Housebuilding in the USA

A study of rationalisation and its implications

MINISTRY OF HOUSING AND LOCAL GOVERNMENT | HMSO 8s. 6d. net

Cover: package delivery and erection of house shell

House package: National Homes, Lafayette, Ind.

Builder: Gateway Corporation, Indianapolis, Ind.

GB

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LONDON: HER MAJESTY'S STATIONERY OFFICE 1966

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Introduction

1. In the summer of 1964, Miss Pat Tindale, a member of the research and development group of the Ministry of Housing and Local Government, spent three months in the United States of America, studying current techniques of house construction. Fifty visits, mainly in the mid-west but covering many parts of the United States, were made to home manufacturers, builders, materials producers, trade associations and individuals concerned with housebuilding.

2. The study was sponsored by the Ministry and by the Royal Institute of British Architects, through the award of the Alfred Bossom Research Fellowship. The United States federal agency for housing—the Housing and Home Finance Agency—advised on the programme and arranged the itinerary. Through their co-operation, it was possible to cover a lot of ground, both literally and metaphorically, in a short time. This service was of great value and was much appreciated; so too was all the assistance received from the building industry in the United States. This opportunity is taken to thank all the individuals, firms and organisations, who so generously gave time and information, and who were the source of so many stimulating ideas. For the sake of clarity, names are not generally mentioned in the text, but a list of visits is given in Appendix 1.

3. Much has already been written about housing in the United States, and some books deal with its constructional aspects; a list of the books which provided excellent background information is given in Appendix 2.

4. This study does not set out to provide a comprehensive review of U.S. housebuilding, or homebuilding as the Americans prefer to call it; it is a report of materials and components seen, techniques and processes observed, and of methods and ideas discussed, during a period of three months, and which, it is thought, will be of interest and relevance to those concerned with housebuilding in Britain. It is written by an architect, and so the descriptions of factory processes and site operations will seem amateur to manufacturers and builders; they are not intended to provide detailed information for specialists, but to give architects an insight into the potentialities and disciplines of designing for industrialised housing as practised in the United States.

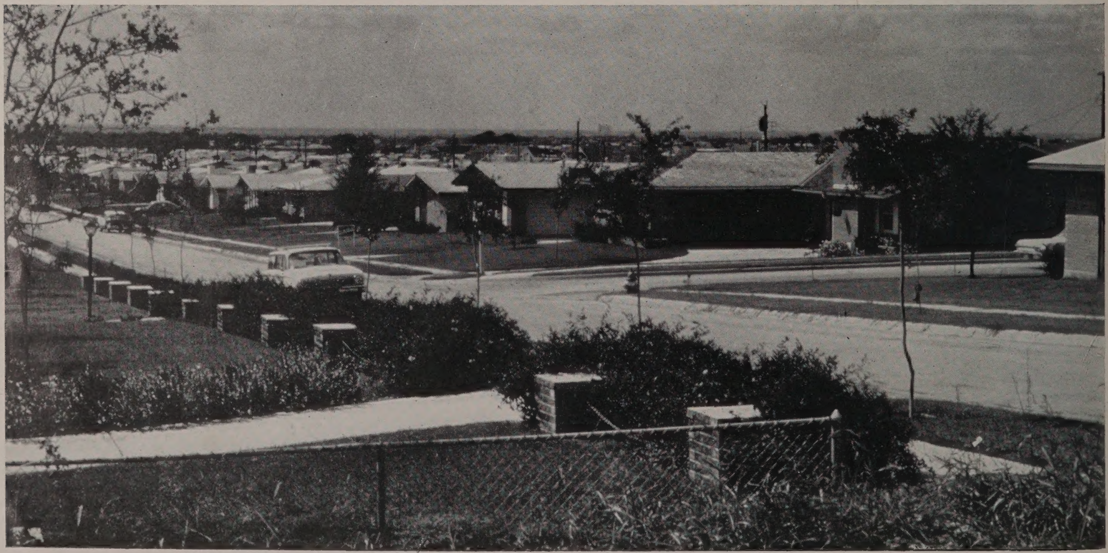
5. For U.S. practice has much in common with British. Houses, rather than flats, predominate, and timber is one of the principal materials used. The traditional U.S. frame house (in British parlance, load-bearing timber panel construction) is built, of course, almost entirely of timber, and with current techniques site labour is used efficiently and the product is good value for money. In the United States, as here, there has been, and is, a need to reduce the amount of site labour used, not because there is a shortage, but because of its high cost. The techniques of fabrication and the site assembly of timber components for housing have been developed continuously over the last thirty years, and the use of these methods has become increasingly widespread. U.S. experience is thus of particular interest at this time when there are many experiments in this country using similar forms and techniques of construction with the same aim of achieving a reduction in site labour. Finally, the study tour provided the opportunity to study other developments in methods of construction, and in new materials and products.

6. The study begins with a brief description of the U.S. housing market, of the people concerned and of the setting within which they live and work. The main part of the report describes frame construction, its development, methods of fabrication, site operations and assembly, and cost and manhours.* The report concludes with chapters on the remarkable development of mobile homes, and on other methods of construction.

* The arrangement of the report in sections on construction, fabrication and assembly means that many elements are referred to in two or three places. To facilitate the extraction of all information on an element or component, a cross reference is given in Appendix 3.

1 suburban development
Sun City, Arizona.
Builder: Del E. Webb, Phoenix, Arizona.

2 suburban development
Dallas, Texas.
Builder: Fox and Jacobs, Dallas, Texas.



The US housing market

7. As the development of homebuilding, and its techniques, are shaped by the requirements of the people for whom the homes are designed, by the community's attitudes towards planning and the financing of homebuilding, and by the geographic and economic conditions of the country itself, the setting within which homebuilding takes place in the United States is described briefly in this chapter. Most of the material has been drawn from *Housing and urban development—U.S.A. A current review*, issued by the Housing and Home Finance Agency* in January 1964.

The customers

8. Increasingly, Americans live in the ever-expanding suburbs, and beyond these suburbs there stretches apparently limitless open country (Figures 1 and 2). With this abundance of potential building land—the United States has an area over sixty times that of Britain, but a population only four times as large—the preference of American families for single-storey detached houses appears to them to be realisable. This demand the American builder sets out to satisfy; from 1954 to 1963, 80% of all the homes built were single family structures, and 69% of the housing stock is of this type. Of the remainder built during this period, there were some attached houses of various kinds, but the majority were flats.

9. Most of these homes (in 1954–63, 82% of all the housing units built) were for sale. By 1963 home ownership had increased to 63% compared with Britain's 43%. Ownership on this wide scale is facilitated by the Federal Government, whose financial policies for housing have developed from measures taken during the early 1930s to secure homes for their occupiers during the depression, and subsequently to encourage private investment in residential construction. Through the agencies of the Federal Housing Administration and the Veterans Administration, the Federal Government insures or guarantees money lent by private investors for mortgages, promising to redeem the mortgage or reimburse the lender in the event of foreclosures. A ½% charge is made for the F.H.A. insurance premium, but this is compensated for by the fact that money lent for F.H.A.-insured mortgages tends to attract slightly lower rates of interest than conventional mortgages. The advantages to the homebuyer of an F.H.A.-insured mortgage are low down payment—as little as 3%—and a term which can be as long as 30 to 35 years; the average loan is for 24 years compared with 15 years for a conventional loan; this, of course, reduces the amount of the monthly repayment considerably and thus lowers the income limits for mortgages. In addition the F.H.A. approves the construction of the houses it insures and inspects the work in progress, so that the purchaser is assured of reasonable standards of workmanship.

10. In post-war years, insured or guaranteed mortgages by F.H.A. and V.A. have been used for 20–50% of the houses built each year. Most of these houses are in the medium price range. For higher-priced houses, conventional financing is more favourable; and in the lower price range it is often adopted of necessity because of the lower constructional standards of the house or because of the extremely limited financial capacity of the purchaser, who may need a second mortgage, and this is not permitted under F.H.A. rules. In addition to making home purchase easier for many families, the F.H.A. and V.A. have had a wider effect on the homebuilding industry. Together with the Federal National Mortgage Association, which provides a secondary market for mortgages, their policies help to smooth the flow of money into homebuilding. F.N.M.A. buys mortgages when credit is tight, in order to alleviate pressure on interest rates, and to keep a supply of funds available for new purchasers. F.H.A. can dispose gradually of properties acquired through foreclosures, thus helping to maintain stable market prices. Finally, builders can obtain construction money more easily for F.H.A.-approved structures.

11. Although the extent to which Federal Government action succeeds in creating stable conditions is a matter for discussion within the industry, there is general agreement that it has been instrumental in increasing the number of potential home-owners and thus the overall turnover of the industry.

12. Of the 18% of housing units built for rental during 1954–63, only a small proportion, 1–2%, were for public ownership. The official policy is that private enterprise should be encouraged to serve as large a part of the need as it can. Rents in public housing are frequently set for each family in relation to its income and not to the size of the accommodation, and there is an upper income limit for admission. The intention is that residents shall remain in public housing only until they have a large enough income to buy or rent decent housing in the private market.

13. Architects as agents for the client are not much in evidence in homebuilding. There are, of course, individually designed houses, but these are few and usually luxurious; public housing schemes are architect-designed. Most housing is initiated by builders or home manufacturers, who may use plans prepared by architects, and there are architects working for manufacturers and materials producers. But for most people in the United States the acquisition of a home involves only a transaction with a homebuilder. Seen in its simplest terms, the U.S. housing market resolves into a dialogue between purchaser—what choices are available to me?—and builder—what shall I be able to sell? Since American families move house a great deal—two and a half times more frequently than Britons—this is a dialogue which is often repeated, not only with young families seeking their first home, but more often with families of maturity and all degrees of affluence. And for many people there is a considerable amount of choice, since within the limits they set themselves, the American homebuilders have been so successful that in many areas the supply of housing exceeds the demand.

The builders

14. There are approximately 50,000 homebuilders in the United States, and in 1963 they produced 1,600,000 housing units—8·4 units per 1,000 of population compared with Britain's 5·9. The average output per builder was 60 units. Though over the years the output per builder has been increasing, there are continuing reasons for the existence of small builders. In 1963, 17% of the houses were produced by builders building only one house, and most of these were by people building their own homes. There are also builders, essentially carpenters, who make

* Now part of the new Department of Housing and Urban Development.

a limited living building one house at a time, using their homes as offices, sub-contracting other trades and producing three or four houses per year. For some, building is a part-time occupation. Then there are new builders continually entering the market, and whose initial operations are on a small scale. Finally, as the centres of building activity are, as a rule, widely separated, builders tend to operate in one location only.

15. The builders visited were selected from the 1% or so who produce 100 or more houses per year and whose total output represents about one-third of the national output; most of them built between 100–300 houses per year: one, exceptional in both output and approach, 3,500 (Levitt and Sons Inc.). These builders were all volume or operative builders, i.e. speculative and not custom builders. Their method of operation is to build a number of show houses on open suburban land. The prospective homeowner then places an order with the builder for the house he wants on a site within the area to be developed. The home is usually available for the purchaser within two months, particularly if a prefabricated construction is used. In some instances the builder may wish to develop the site in sequence, in order to achieve efficient production with on-site fabrication, and in this case purchasers may wait six to nine months for their houses. Usually, the builder's speed is governed more by the rate at which he can sell houses than by the time actually required for building. An interesting confirmation of the builder's confidence in his ability to produce houses to a given schedule is that, under certain circumstances, he imposes similar conditions on his customers. In order to stimulate sales the builder may reduce the minimum down payment by a considerable amount if the purchaser is willing to paint the inside of the house and to grade, rake and seed the garden. This reduction is conditional on the work being completed within 10–20 days of a specified date. By this means, a purchaser can move into, for instance, a £4,000 house for a down payment of only £20.

16. Most builders build in the timber load-bearing panel construction which is traditional in the United States, and they are able to choose from a wide range of alternatives the methods by which they select and order materials and components, and organise site operations. At the one extreme, the builder can do everything for himself—design the houses, buy the materials, and hire and supervise the labour. At the other extreme, he can accept a fully designed and detailed house supplied in package form by a home manufacturer, and sub-contract all the labour. The processes of supply, manufacture and distribution are complex, and in many cases interwoven: to clarify the terms used, the main participants, and the ways in which they are connected, are shown in outline in Figure 3.

17. The builder's choice of policy will be influenced by such factors as his annual output, his organisational ability and financial position, and the availability of labour. Small volume builders, those with an annual output of, say, 50 houses or less, usually obtain their materials from the local builder's merchants —in some cases and to a varying extent, pre-cut to size—and carry out most of the fabrication on site. On the other hand, a new builder with a small but increasing volume may find the home manufacturer's services useful in establishing his business. The home manufacturer can assist him in financing both the purchase of land and the construction of the houses, in supplying material for advertising on television and in the newspapers, with the display and furnishing of the show houses and in providing mortgage acceptance facilities for the homebuyers. The use of a manufactured home also reduces the number of office staff, and the storage and equipment required by the builder, since the house package can contain virtually everything needed for the construction of the house.

18. Generally, builders using manufactured homes tend to have a larger volume than the others, perhaps because more houses can be built with the same staff, and because of the faster turnover of capital. On the other hand there is a certain knack in assembling manufactured homes, without which some of the speed and reduction in site labour is lost, and small builders may not get sufficient repetition to acquire this skill. Again, the small builder may more easily be able to draw on sufficient labour to permit site fabrication. Another factor is the relationship between site and factory labour rates; where site labour rates are not much higher than factory rates there is less incentive to use manufactured homes.

19. Some builders who produce 250 or more houses a year and who have a flair for organisation consider that they can achieve better value for money by fabricating for themselves. Because of the volume and continuity of their output they are able to buy materials in bulk direct from the producers at prices similar to those paid by home manufacturers. In this way one middleman is eliminated and the transport of components is reduced and simplified. More flexibility in design is possible. These factors offset, perhaps more than offset, the inherent loss of efficiency due to the builders' smaller and more varied production.

20. The largest builder—Levitt and Sons Inc.—purchases all material required and sub-contracts all labour. There is some pre-cutting of material but little preassembly.

21. Whatever policy the builder adopts in design and construction, he receives considerable assistance from the large and progressive industry of component and home manufacturers and materials producers.

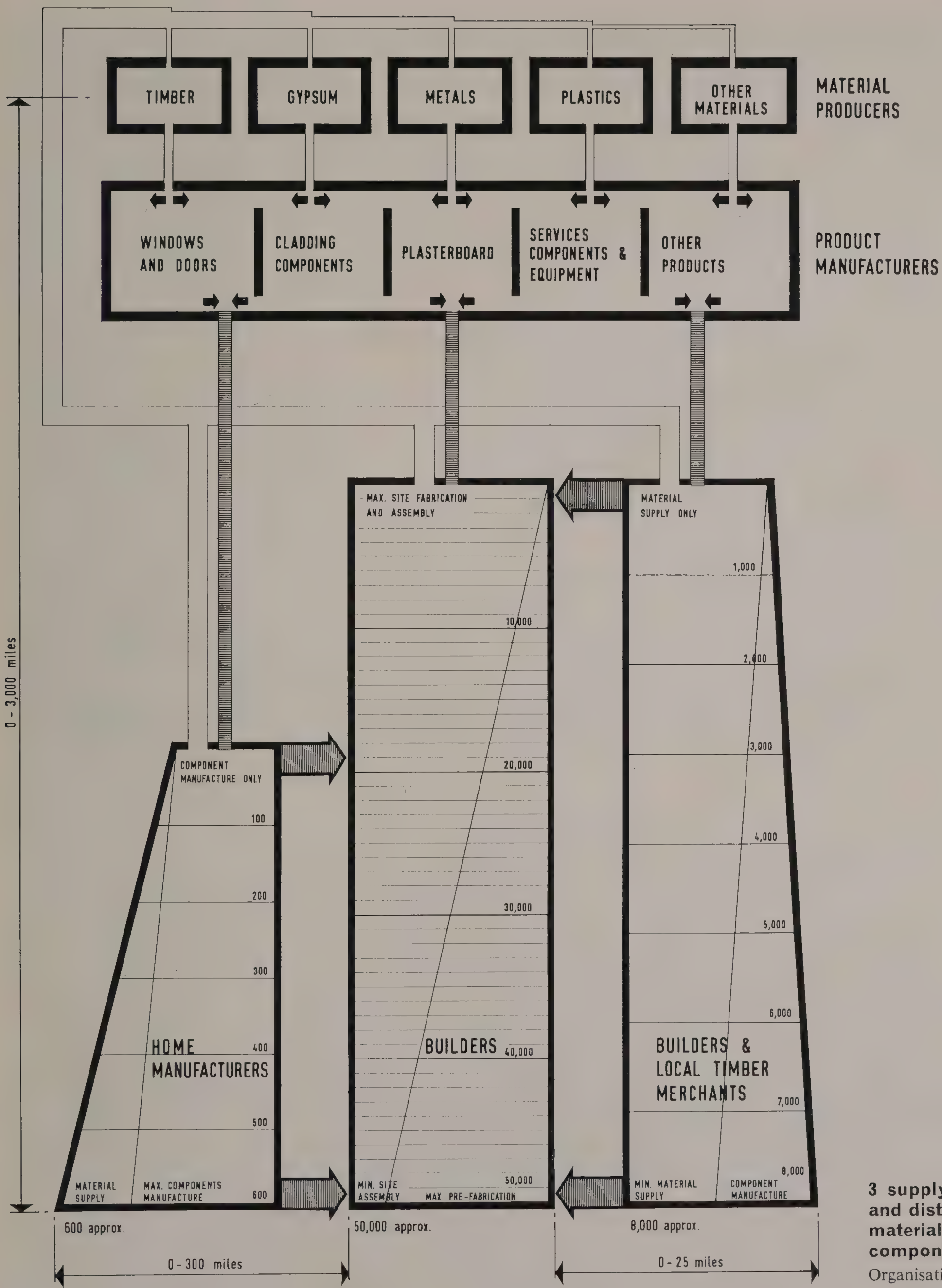
The industry

Home manufacturers

22. The development of the home manufacturing industry first gained impetus in the 1930s. Before this, from the end of the 19th century onwards, there had been a great number and variety of attempts to prefabricate houses. These ranged from ideas based on radically new concepts of house design, new materials and methods of production, such as Buckminster Fuller's Dymaxion house in 1928, through various in situ concrete or precast panel constructions, to pre-cut and packaged versions of the traditional timber house, such as that produced by the E. F. Hodgson Company in 1892.* The latter type, though producing a greater number of houses than the others, were in a minority; understandably so, since innovators, almost by definition, have the urge and vision to exploit new ideas.

23. In the view of the Home Manufacturers Association, a decisive factor in the emergence of home manufacturing as an industry was the setting-up of the Federal Housing Administration in 1934, with its promise of volume and continuity in homebuilding. However, the Federal Housing Administration tended to put a premium on the more experimental ideas of the early innovators, for its standards of appraisal were based almost entirely on the traditional site-assembled wood frame construction. Building codes, too, often specified in detail, and demanded, on-site construction; in addition, there was considerable variation between codes for different localities. Perhaps, also, the home manufacturers came to realise that some of the new techniques were less easy to put into production than they had at first hoped, and that for their products to be used in quantity, the already trained site workers and existing channels of distribution would have to be used; in some cases there was some initial resistance by the unions to the adoption of new techniques. There was also the question of public acceptance; would sufficiently large numbers of people be willing to make their largest financial outlay on a product that appeared fundamentally new and untried?

* For a comprehensive list, see A. F. Bemis, *The evolving house*, *vol. III*, *Massachusetts Institute of Technology*, *Cambridge*, *Mass.*



3 supply, manufacture and distribution of materials and components:
Organisational chart.

24. Nevertheless, there were a number of significant experiments in the latter 1930s which contributed a great deal to the general knowledge and experience of prefabrication, e.g. the stressed skin plywood panels of Gunnison Homes, the insulated steel panels of General Houses, and the steel and timber panels of American Houses. Between 1935 and 1940, 10,000 houses, 1% of the total, were built by some 30 manufacturers.

25. By the end of the 1930s the mainstream of development lay in prefabricated replicas of the traditional timber house. The most successful pioneers of this approach were the brothers George and James Price, who set up National Homes in 1940, and by 1942 had produced 3,660 houses. This firm is now one of the longest established and has the largest output of them all —seven factories producing in the peak year of 1955 20,000 homes. During the war the production of prefabricated homes had been stepped up because, as they could be built easily and speedily with a minimum amount of site labour and where necessary taken to pieces and re-erected on other sites, they could best satisfy the needs of emergency war housing. Unfortunately, however, because of the need to be economical in materials, standards were lowered, and for a time this gave prefabrication generally a second-rate reputation.

26. After the war prefabrication advanced again when it was found that home manufacturers could produce small houses more cheaply than local carpenters. Prefabricated houses also gave the returning G.I.s opportunities to solve their housing problems swiftly, because they could carry out much of the site assembly themselves. A typical example of this date is the National Homes house shown in Figure 4. It has two bedrooms, living room, kitchen and bathroom, a total area of 860 square feet, and the purchase price was £2,300. In 1950, home manufacturers produced 50,000 units per year, 5% of the total output.

27. Gradually home manufacturers began to increase the range of items offered to the builder or prospective homeowner. Originally this had consisted of external wall, and roof panels; fully glazed windows were now inserted in the factory, cladding fixed, and partition and flooring systems supplied. A further advance was that the manufacturer began to buy in heating and air-conditioning equipment, bathroom and kitchen fittings, plumbing and electrical materials and components, even carpets and light fittings. In fact, the house package could now include almost everything except the foundations. All these components were loaded on to one, or perhaps two, covered trailers and hauled by road to the site of the house to be constructed (Figure 5). The economic radius for delivery was, and is, generally considered to be 200 miles, with a maximum limit of 300 miles. Output had been rising steadily, and in 1960, 127,000 units, 13% of the total, were produced, and these houses were generally larger and more varied than those produced in the 1940s.

Builders' merchants and local timber dealers

28. This progressive increase in the output of the home manufacturers produced an appreciable decline in the local timber and builders' merchants' own trade, so they too began to offer manufactured components such as roof trusses and pre-hung doors, thus increasing the value of their sales to those builders who were using conventional methods of assembly. By this time the machines and jigs which had been developed for the home manufacturers had become much less expensive, so that it was now economically possible for the local merchants to purchase this equipment for their comparatively small volume of business. For some, the next step came in the production of wall panels and the offer to their local customers of a house package service. With their small output and radius of operation, and the high degree of standardisation of constructional technique, the local merchants were able to offer considerable flexibility in their house designs. In fact, it is now possible to order at a reasonable price a house package of preassembled units, for a one-off individually designed house. Such a house would have its own plan and elevational arrangement and would be constructed of components and equipment normally stocked by the merchant. This, in turn, has caused the house manufacturers to increase the range of their own products.

Current production

29. In 1964, the home manufacturers and builders' merchants together produced almost 250,000 manufactured homes, 22% of the total output of houses. The houses ranged in size from the smallest to the largest, and in quality from the inexpensive to the luxurious. It is therefore apparent that in appropriate circumstances prefabricated houses are valid throughout the whole range of the market.

30. There are now more than 600 home manufacturers, with a wide range in output. It is estimated that—

14%	produce less than	100	houses	a year
60%	,,	100–500	,,	,,
8%	,,	500–1,000	,,	,,
18%	,,	more than 1,000	,,	,,

Among the larger firms are several producing 3,000–4,000 per year, and one firm producing 15,000. Total output is rising by 10% each year.

31. Though the great majority of manufactured homes are of timber load-bearing panel construction, there are other constructions, many of them being utilised for houses of high aesthetic quality, in production on a small scale for a small market; e.g. timber post and beam systems, and systems using structural or sheet steel and foamed plastic sandwich panels. In 1961, in order to foster the advancement of new ideas, the Federal Housing Administration launched an experimental housing programme, in which insurance will be given to pilot schemes exploring new and untried aspects or techniques that are likely to reduce housing costs, raise living standards, or improve neighbourhood design.

Mobile home manufacturers

32. One of the most remarkable features of the U.S. homebuilding industry since the war has been the development of the mobile home. From their pre-war origins as travel trailers or caravans, they have developed into permanent homes with a full range of amenities. With the trend for traditional homes, both manufactured and site-constructed, to grow larger and more costly, a gap has been left in the market for the compact, easily run, inexpensive home. This market the mobile home industry is successfully capturing; in 1964, one-third of all homes priced at £3,500 or less were mobile homes. In 1962, 172,000 mobile home units were produced, compared with 186,000 manufactured homes; a bonus of 18% for the officially recorded housing starts. In order to compete with both the mobile home manufacturer and the local builder's merchant, several home manufacturers have started to adopt mobile home manufacturing techniques. Three-dimensional units, forming house sections, are produced on assembly lines and placed in position on site with mechanical equipment. This leads, of course, to a further reduction in site labour.

Materials producers

33. The home manufacturers and the mobile home manufacturers form a specialist industry whose sole purpose is homebuilding. Both they and the conventional homebuilders receive considerable help from the materials producers who serve the whole construction industry. For example, the most extensively used material—timber—can be supplied planed, cut to length,

4 prefabricated house 1946
Manufacturer and builder: National Homes, Lafayette, Ind.

5 package house trailers
Manufacturer: National Homes, Lafayette, Ind.

end-treated with water-repellent preservative and bundled; window and internal door frames can be machined and supplied in knock-down form. A major plasterboard firm considers that a basic part of its job is systems engineering—i.e. the development of methods of using the material, and the production of accessories to make its use simple and the result of a high quality. A firm of tool manufacturers has produced tools with built-in jigs, which facilitate the positioning of the tool on the work.

34. Although this enterprising spirit is encouraged by the existence of spare capacity in the industry, independent development is made possible because of the continuing use of a standard though evolving method of construction. In the U.S.A. the location of timber elements and the way in which they fit together is as universally accepted as is the location of bricks and ties in an 11″ cavity brick wall in Britain.

Research organisations

35. In addition to the research and development work carried out by materials producers and home manufacturers, there is also the work of the trade associations, universities, and government research organisations. For example, the National Association of Home Builders has its own research laboratories, and every two years builds a research house to test out new ideas. The Small Homes Council of the University of Illinois carries out experiments and produces papers on the planning and technical aspects of house design. In addition to research work, the University of Michigan runs a four-year course in light residential construction for potential managers, designers and technologists. Other long-term development work on building materials and structures is carried out by the National Bureau of Standards and the U.S. Forest Research Laboratory.

Resources

36. From the preceding description it will be seen that home-building in the United States, unlike its British counterpart, is fortunate in the abundance of its resources. There is no shortage of land, and builders can generally obtain as much as they need. The rising cost of site development is, however, leading to the consideration of house types, such as terraces and clusters, which occupy less land than the single-storey detached house. Materials are mainly home-produced and plentiful, and the market is very competitive. Although unskilled labour is plentiful, in some areas there is a shortage of craftsmen, and as all labour is expensive there is every incentive for the builder to use it productively. Financial resources also appear to be plentiful since credit is readily available for any potential homeowner with adequate income.

37. The cost of using these resources varies considerably between the two countries.* The comparisons are complicated by the different types of construction—load-bearing brick and timber frame—and by the different relative values of materials and labour. For example, constructional softwood costs 25–50% less in the United States than in Britain, while common bricks cost 100–150% more. Factors affecting the relative cheapness of timber in the United States are the nearness of the houses to the source of supply, the standardisation of the sizes used and overall volume of timber used. The high cost of bricks, on the other hand, is probably due to the fact that clays suitable for brick making are found only in limited areas of the United States, and that less use is made of the material.

38. Hourly wage rates are much higher in the United States than in Britain—in 1964 skilled site labour received from 27/– to 40/– and unskilled site labour 15/– to 30/– per hour. Comparable British figures were 6/3 and 5/5 for skilled and unskilled labour respectively. Factory labour rates in the U.S. in 1964 were 16/– to 22/- per hour. But the differential between United States and British "take home pay" is less than differences in hourly rates suggest because, in the United States, there are insignificant bonus payments and a shorter working week. On average 37 hours are worked each week compared with 48 hours including eight paid at overtime rates in Britain. Even so, ignoring insurances and holidays-with-pay schemes, United States weekly earnings on building sites are probably three times those in Britain.

The product

Design

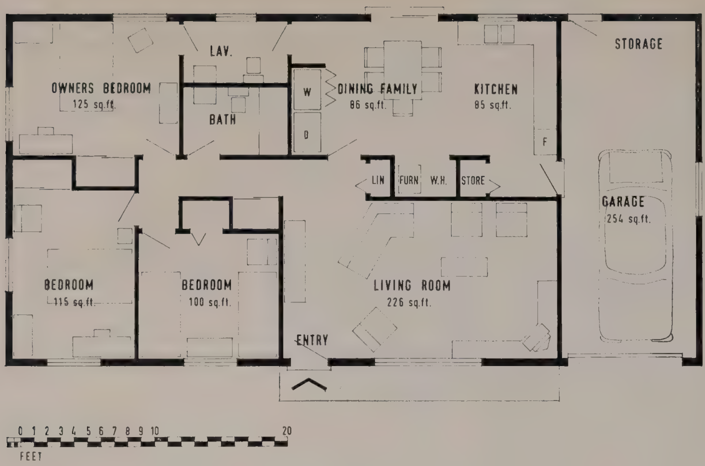
39. The most popular type of American house now being built is the single-storey detached house with living room, family room and kitchen, three bedrooms, a bath-and-a-half, and a garage (Figures 6 and 7). In area it averages 1,100 square feet, excluding the garage.† Plan A (Figure 8) shows a typical example. As is customary in the United States, the entrance door opens directly into the living room. The kitchen is well-arranged and excellently equipped. A cooker, with separate range top and built-in oven, and a 13-cubic foot refrigerator are usually included in the building contract. Attached to the kitchen is the family room used by the family during the day and for dining. In an alcove off this space, behind louvred doors, are the washing machine and drier. The half bathroom—w.c. and basin—is adjacent to the family space and is also directly accessible from the main bedroom—a good example of dual use. The bathroom

* This information is drawn from P. A. Stone—*International comparisons of building costs*. Institute of Statistics Oxford Bulletin No. 22, 1960; and subsequent work by the Building Research Station.

† In U.S. calculations floor areas are measured to the outside faces of external walls; American figures are thus 6–10% higher than those which would be obtained by British methods of calculation. Except where otherwise stated, American figures are used in this bulletin.

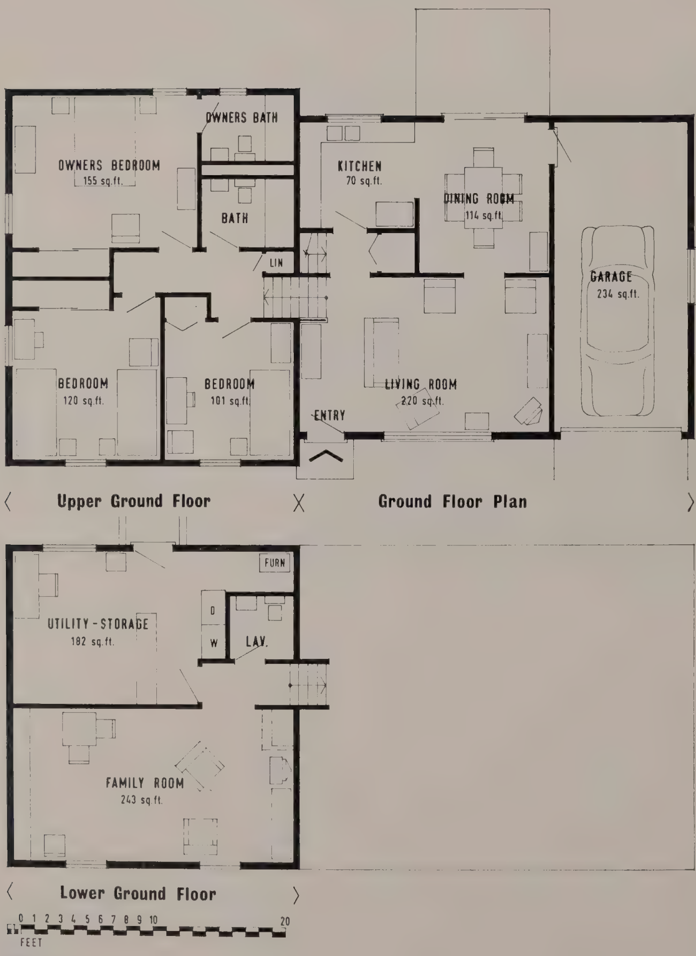
6 typical house — external view
Builder: Andrew Place and Company,
South Bend, Ind.

7 typical house — external view
Builder: National Homes, Lafayette, Ind.



Plan A

area	1110 sq ft
+garage	254 sq ft
	1364 sq ft



Plan B

area	1468 sq ft
+garage	234 sq ft
	1702 sq ft

8 typical house plans — single-storey and split-level

Designer: Pease Woodworking Company, Hamilton, Ohio.

Areas measured to inside faces of external wall.

itself has a shower fitting and enclosure mounted over the bath, the basin is mounted in a vanitory unit and bathroom fittings such as medicine cabinets and towel rails are provided. Generous storage is provided throughout the house and in the garage. The house is usually heated with a gas-fired ducted warm air system, the ducts also being available for air-conditioning.

40. Though there is some variation in cost in different parts of the United States, the average purchase price of such a house, including a land price of approximately £1,000, would be of the order of £5,500. These average figures are derived from a wide range of houses of varying areas and prices. Some idea of the range available may be obtained from the following tables, which are based on F.H.A. mortgage-insured houses built in 1963.

Price	
less than £4,000	6·8%
£4,000–4,999	21·6%
£5,000–5,999	33·4%
£6,000–6,999	21·1%
£7,000–7,999	9·5%
£8,000 and over	7·6%
	100%

Area	
less than 800 sq. ft.	4·2%
800–899 „	6·6%
900–999 „	16·6%
1,000–1,099 „	19·9%
1,100–1,199 „	13·7%
1,200–1,299 „	11·2%
1,300–1,399 „	7·6%
1,400–1,499 „	6·0%
1,500–1,599 „	4·9%
1,600–1,799 „	5·8%
1,800 sq. ft. and over	3·5%
	100%

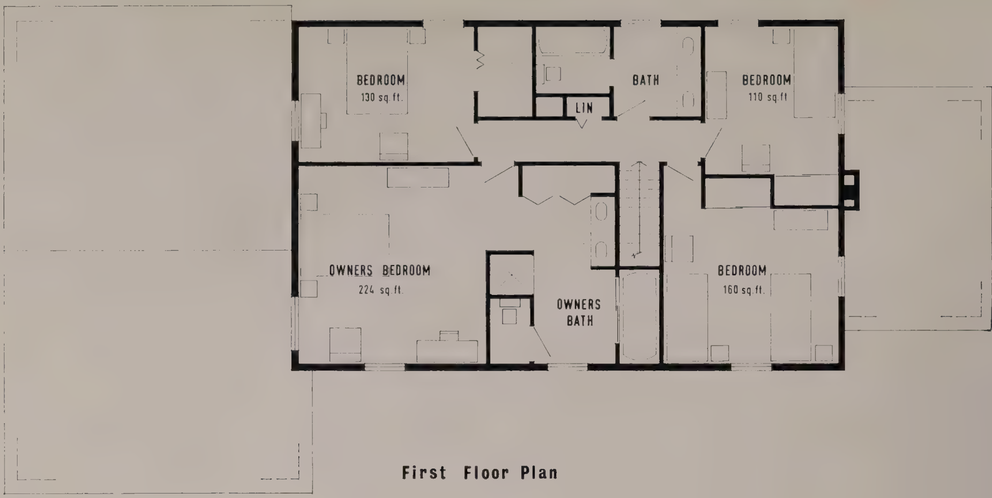
41. International comparisons of housing prices are notoriously difficult to make, but the following analysis may be of interest. In order to equate the purchasing powers of the pound and the dollar, it is assumed that 5/– spent in Britain will buy one dollar's worth of goods in the United States; it follows that the average American house costing the equivalent of £5,500 should be available in this country for £3,900. With a 30-year mortgage at 5¼% and a down payment of 3% the monthly repayments on the American £5,500 house, including insurance and local taxes, amount to £39. 10/–. On average, the mortgage repayment and insurance and tax payment represent 16% of the American family's income; this means that one family in three has sufficient income to buy an average price house. But given the same mortgage facilities and spending the same proportion of income, only one family in twelve would be able to buy the £3,900 equivalent in Britain.

42. Houses of the type of Plan A are sometimes built over a semi-basement, the garage being lowered to ground and an entrance being created at that level. The lower storey is left with an interior finish of in situ concrete or block, and provides a large hobby or family room, storage and utility space. In this way the area of the house is virtually doubled with an increase in cost of only 20–25%.

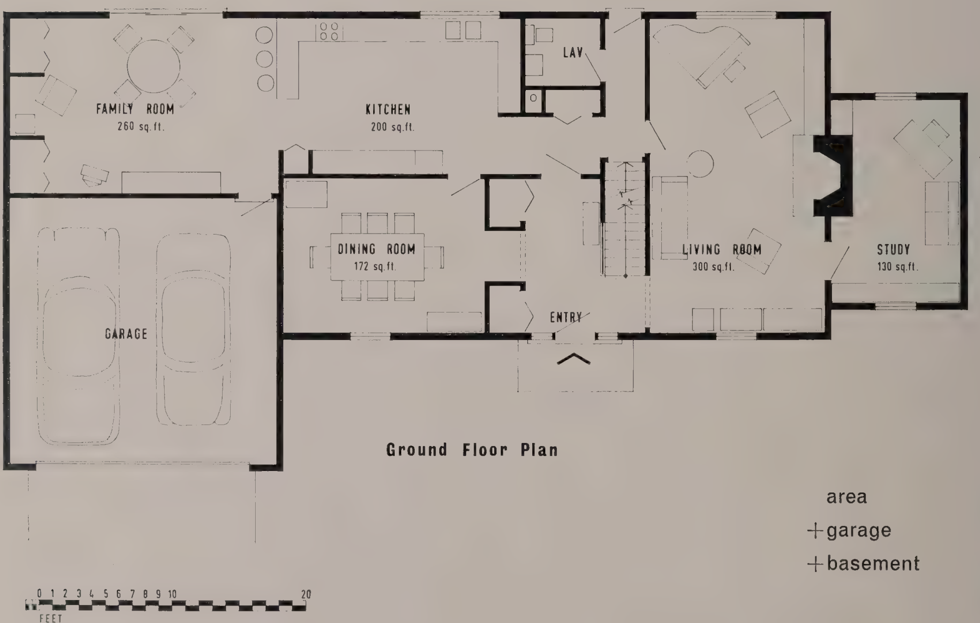
43. Another and popular type of plan is the split level (Plan B, Figure 8) which is often built regardless of the natural contours of the ground and is then integrated with its surroundings by considerable reshaping of the land. The plan gives an excellent internal relationship between the sleeping, living and activity areas of the house.

44. Plan C (Figure 9) is shown as a typical example of the large two-storey house. It has an area of 2,340 square feet with living room, dining room, study, family room, kitchen with breakfast bar, four bedrooms, two-and-a-half baths, lavishly arranged, and a two-car garage. There is considerably more variation in the purchase price of houses of this type, but there are certainly some available at £8,000–£10,000.

45. Terrace houses are generally similar in plan to those now being built in Britain.



First Floor Plan



Ground Floor Plan

area	2340 sq ft
+garage	430 sq ft
+basement	920 sq ft
	3690 sq ft

Plan C

9 typical house plan — two-storey

Designer: Pease Woodworking Company, Hamilton, Ohio.

Areas measured to inside faces of external wall.

46. The production of house plans by home manufacturers and others without reference to the site on which the houses are to be built has fewer disadvantages than it would in Britain. As the houses are generally built on large sites, privacy can usually be obtained by measures taken within the site itself. Although most architects believe that it is important to orientate houses in order to get sunlight in the living room, this is not as important a factor in most parts of the United States as it is throughout Britain, and many developers do not give orientation a high priority. House plans are usually produced with several types of elevation, with different styles based on various indigenous traditions.

Performance and amenity standards

47. Building standards are controlled by local building codes or byelaws, which are frequently based on specification rather than performance standards, and which in detail differ considerably from one another. The standards on which this section is based are the Minimum Property Standards of the Federal Housing Administration, which apply to all houses financed under the federal mortgage insurance scheme, and they appear to be representative of the standards adopted by the home-building industry as a whole.

48. *Lighting.* Natural lighting is required in all habitable rooms except the kitchen; windows, doors or rooflights are required to have an area equivalent to 10% of the floor area. Artificial lighting must be provided in all rooms, and in the kitchen must be distributed to provide effective illumination of the working and dining areas.

49. *Heating and thermal insulation.* Standards are not specified in the form of U-values for elements of structure. The requirement is that the total calculated heat loss from the house shall not exceed 50 BThU's per hour per square foot of the total floor area to be heated to 70°F., of which not more than 30 BThU's per hour shall be through the walls, not more than 15 BThU's through the basement or crawl space, or alternatively not more than 5 BThU's through the slab; for ceilings below unheated roof spaces, a U-value of 0·15 is given. This method allows for regional differences in outside design temperatures (the range is from +20°F. down to −30°F.) for varying proportions of window to wall area, and for some latitude in the distribution of insulation. In practice, insulated ceilings commonly have a U-value of 0·12, and walls range from 0·20 to 0·08. The heating equipment is required to have sufficient output to overcome the calculated heat losses.

50. Roof overhangs or other shading devices are desirable in many parts of the United States to keep the summer sun off windows in the middle of the day and thus to prevent heat build-up in the house.

51. *Condensation control.* In timber frame buildings it is necessary to obviate the condensation of water vapour within the cavities of the building. Moisture is produced inside the building by the occupants, in respiration, cooking, bathing and washing. The need to maintain high internal temperatures and comfortable conditions in winter has led to the adoption of better methods of weather stripping, and of wall, floor and roof constructions which have a high degree of thermal insulation, as well as external surfaces which are resistant to air infiltration. It is no longer easy for moisture to leak out of the building. Whenever the vapour pressure inside the building is greater than in the cavities, moisture is drawn into these cavities. Because the thermal insulation retains heat within the building, the temperature of the air in the cavities and on the inside surface of the cladding or sheathing is low, and condensation occurs. If the cladding is impervious or highly resistant to moisture penetration, the condensate is trapped and the conditions produced are conducive to the decay of timber. In some parts of the United States it is possible for the same actions to take place in reverse, i.e. from outside to inside, with air-conditioned buildings in hot humid atmospheres. To avoid these conditions, vapour barriers are necessary near the warm surfaces of walls, floors and roofs.

52. The American Society for Testing Materials and the Building Research Advisory Board have developed test procedures* for establishing the effectiveness of vapour barriers; these are based on permeance, resistance to alternate wetting and drying, to prolonged soaking, to decay and abrasion, and to plastic flow and elevated temperatures. The unit of permeance—the perm—is defined as a vapour transmission rate of one grain of water vapour per square foot per hour per inch of mercury pressure difference. The permeance ratings of vapour barriers are usually given by manufacturers in their technical literature. For example, foil-backed plasterboard 0·30 perms, aluminium foil 0·02 perms, ½″ douglas fir plywood 5·50 perms, 4″ brick 2·20 perms. The F.H.A. requirements is that where the U-value of the wall is better than 0·25, and where the cladding or sheathing have a vapour transmission rate of less than 5 perms, a vapour barrier shall be provided with a value not exceeding 1 perm.

53. *Ventilation.* Natural ventilation is required in habitable rooms; the equivalent of 4% of the floor area must be provided in openable windows, doors, rooflights or other openings in walls or roof. In kitchen and bathrooms, mechanical ventilation is a permissible alternative to natural ventilation, at rates of 15 and 8 air changes per hour respectively.

54. *Water supply.* There are no requirements for cold water storage. Hot water must be provided, and the requirements are based on the number of bedrooms and bathrooms in the house, and related to the capacity and input rating of the heater.

55. *Electrical supply.* Double-socket outlets are required in all habitable rooms so that no point along the floor line of usable wall space may be more than 6′ 0″ from an outlet. Additional outlets are required between all doors and between doors and fireplaces when these are sufficiently separated for the placement of furniture. In kitchens at least two double-socket outlets must be provided over counter work surfaces.

56. *Fire resistance.* Party walls between houses in different ownership are required to be non-combustible and to have a fire resistance of two hours. In other walls, and in floors and ceilings separating dwellings, a fire resistance of 45 minutes is required.

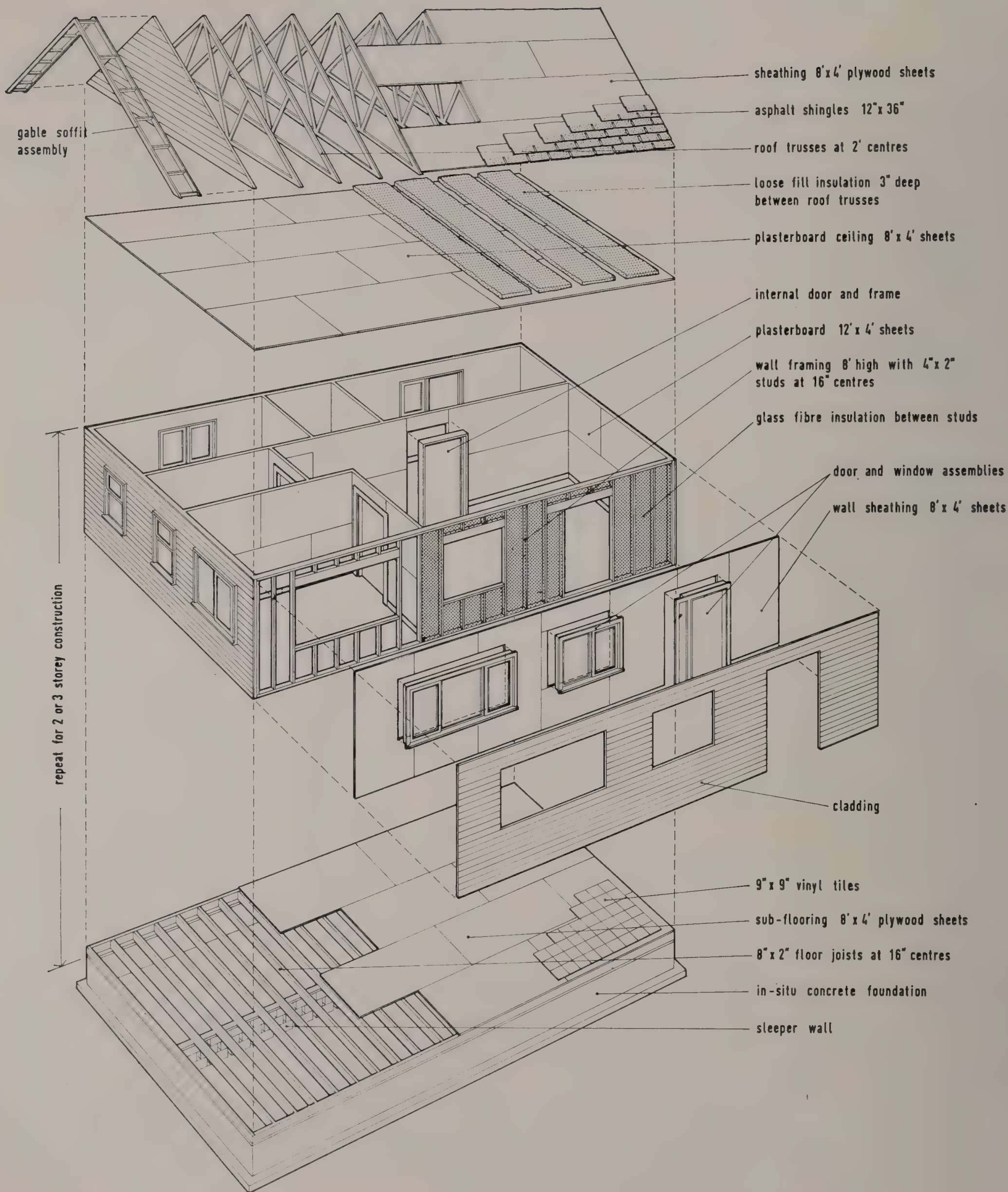
57. *Sound insulation.* There appears to be no requirement for sound reduction.

58. *Loading.* The requirements are rather higher than those recommended in the British Standards Code of Practice CP3 Chapter V Loading, about a third extra for the live loads on floors and roofs, and for wind pressures, almost twice as much as the recommended value for the most extreme exposures.

59. *Ceiling heights.* The minimum ceiling height is 7′ 6″ for habitable rooms with flat ceilings, although a minimum distance of 7′ 0″ is permitted from the floor to the underside of beams or girders when they are spaced at 48″ centres or more. In halls a minimum height of 6′ 8″ is permitted; this is sometimes useful for the location of high-level warm air heating ducts between the levels of hall and habitable room ceilings, so that wall outlets can be provided at high level in habitable rooms adjacent to halls. A minimum ceiling height of 7′ 0″ is also permitted under suspended luminous ceilings or panels. In rooms with sloping ceilings a ceiling height of 7′ 6″ is required for at least half the room area.

60. In practice, because of the universal use of standard 8′ 0″ × 4′ 0″ sheet materials, 8′ 0″ ceiling heights are widely used.

* The test procedures are described in Publications Nos. 445, 596, 998 and 1037 of the National Academy of Sciences and National Research Council, Washington, D.C.



10 platform construction:
General arrangement.

Building techniques - frame construction

Development

Form of construction

61. Almost all present-day homebuilding in the United States is based on the well-established, traditional wood frame construction which has been used from the time of the earliest European settlers. Leaving countries in which wood was the customary material for housebuilding, timber still seemed for them the obvious choice because of the plentiful supplies available on the eastern seaboard of North America. So strongly was this tradition implanted, that, as the use of stone and brick in housebuilding spread in England, its classical details were translated on the other side of the Atlantic into timber. Many of these buildings, some of them now over three hundred years old, still stand and are in use, thus demonstrating the essential durability of the material and construction.

62. Nowadays it is the platform system of frame construction which is most generally used; this is shown in Figure 10. Over the years it has become highly standardised. The wall frames are 8′ 0″ high and consist of 4″ × 2″ studs at 16″ centres, with top and bottom rails of the same section. Roof trusses, which have now almost entirely superseded rafters and ceiling joists, are also made from 4″ × 2″ members at 2′ 0″ centres, with a range of slopes based on simple fractions of twelve. Floor joists at 16″ centres are commonly of 8″ × 2″ members. The wall, roof and floor framing is lined internally, and sheathed externally with sheet products based on wood and gypsum, and manufactured in 8′ 0″ × 4′ 0″ sizes.

63. These dimensional standards, evolved by builders and the industry, have been consolidated in U.S. Government publications such as the Federal Housing Administration's Minimum Property Standards and the Department of Agriculture's Wood Frame House Construction. They, in turn, exert considerable influence on the design of new products. There is therefore a natural incentive for house plans to be based on multiples of 4′ 0″ or 2′ 0″ in order to make the most economical use of materials, but where plans are not worked out on this method, the 16″ and 24″ dimensions are carried through in all but the end bay of the building shell.

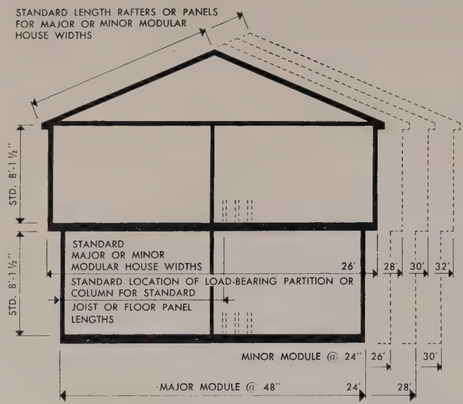
64. Not only were the sizes standardised but they were so rational that in the 1920s Mr. A. F. Bemis was able to base his theory of modular co-ordination, with its principle of the 4″ cube, directly on existing practice. The presentation of this theory undoubtedly clarified and gave precision to the work of later designers. During 1962–64, the National Lumber Manufacturers Association published two manuals on the Unicom method of house construction, which it had commissioned Home Planners Inc., of Detroit, and their architectural consultant, Mr. R. B. Pollman, to prepare. Their primary object is to improve the methods of using timber and wood products in homebuilding, and they appear to carry the standardisation and rationalisation of wood frame house construction to the ultimate limit. Following an analysis of house forms, the Unicom manuals set out a dimensional basis for planning, and dissect the structure into a set of simple elements, suitable for site or shop fabrication. The diagram of platform construction in Figure 10 has been based on Unicom principles. More details are shown in Figure 11. The method of arranging components within these elements is shown in the manual, and schedules of the lengths and sizes of timber required for the full modular range are given (Figures 12 and 13).

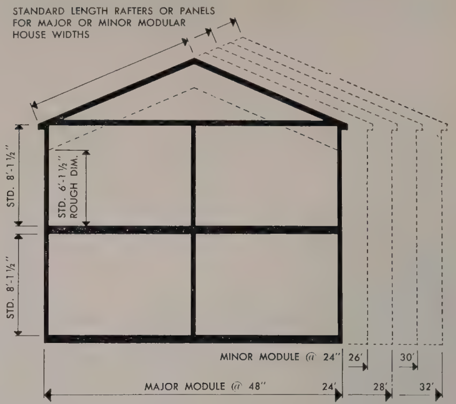
65. The differences between the Unicom publication and technical data on British systems of construction are interesting and significant. Unicom is, of course, produced by a trade association for general use, while the British information comes from the designers or manufacturers of building systems in production. Because of this, Unicom is more akin to a code of practice than to a system handbook. The method of construction is specified in sufficient detail for prefabricated components to be obtained from any manufacturer by simple reference to the Unicom manual. On dimensions, Unicom, while opting for the outside modular co-ordination system, i.e. 4′ 0″ and 2′ 0″ multiples measured to the outside faces of external wall studs, also expounds the inside system and lists its disadvantages. The implication is that, in certain circumstances unforeseeable by the designers, the inside system may prove more advantageous than the recommended one.

Similarly, though using only modular components, Unicom sets out the rules for dimensioning and coding non-modular components. Understandably, Unicom deals with timber framing and sheathing. It presents a range of modular timber windows but does not detail them or give information on the aluminium inserts. There is no information on cladding or on lining materials. Members for roof trusses are designed but no details of connectors are given. Only general information is given on internal timber doors and frames. These omissions, which in a British publication would be sufficient to preclude a system from serious consideration, are not, in the context of U.S. homebuilding, limitations at all, since already other sections of the industry—window and cladding manufacturers, the producers of roofing materials and truss connectors, and of pre-hung doors—are all working within the general outline of the concept which Unicom details so precisely. Similarly, no assembly details are required since the way in which a window fits into a wall (see paragraph 81), or a roof truss sits on top, are common knowledge. Of course, nailing techniques are important but these have already been dealt with in official publications.

Method of assembly

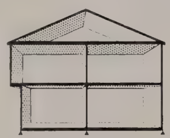
66. To this gradual standardisation and rationalisation of the elements of the wood frame house there has been added in the last thirty years a similar evolution in the methods of production and fabrication. Originally the house was erected stick by stick, and the first development came in the assembly and nailing of the wall framing on the ground or site slab, adjacent to its final position; these frames were tilted up in complete house wall lengths. The next step was the fabrication of the wall panels in a workshop away from the site, and the pre-cutting of other members such as rafters. The off-site manufacture of windows had preceded that of the wall panels, and some manufacturers began to fit the windows in the wall before delivering the panels to the site; the sheathing was added for stiffness, and cladding and glazing followed. A few manufacturers fitted the insulation, and one or two the plasterboard lining. The next important development was that of roof trusses, which eliminated the site fitting of roof and ceiling members, and did away with the need

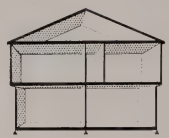




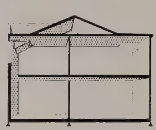
The basic cross-section shows two, standard-height, rectangular living areas with floor space varying according to modular base dimensions. Most standard roof types applicable to one-story are used for two-story designs. The second-floor area is enlarged by projecting the floor system, front and rear walls, and roof construction beyond the first floor. To accomplish this, the standards provide a 24-inch modular increment.

Interior load-bearing elements of two-story houses must be positioned to the precise dimension of a major or minor module, and to the most economical standard floor spans.





Overhangs, on the 24-inch module, may be projected entirely to the front or to the rear, or split equally into two 12-inch increments front and rear.

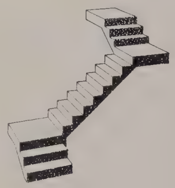


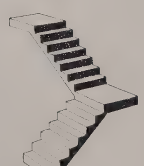
A lower roof line results from the cut-eave, two-story design. Standard rough dimension is 6 feet 1½ inches.

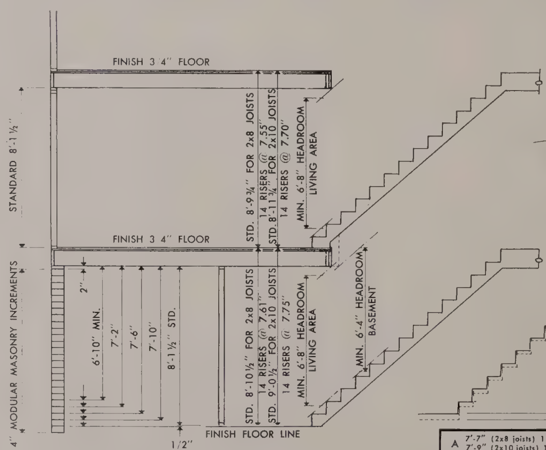
Two story houses, designed within the modular coordination system, are readily adapted to component construction. Consideration should be given to size of components and handling methods for second-floor wall and roof units.

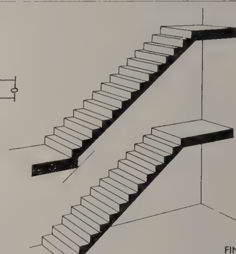
STAIRWAYS

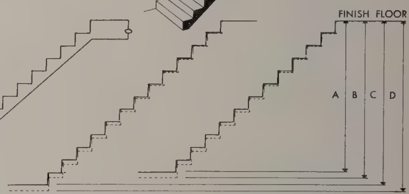
FOR BASIC HOUSE TYPES











A	7'-7" (2x8 joists) 12 risers @ 7.58" 7'-9" (2x10 joists) 12 risers @ 7.75"	C	8'-3" (2x8 joists) 13 risers @ 7.62" 8'-5" (2x10 joists) 13 risers @ 7.77"
B	7'-11" (2x8 joists) 12 risers @ 7.92" 8'-1" (2x10 joists) 12 risers @ 8.08"	D	8'-7" (2x8 joists) 13 risers @ 7.92" 8'-9" (2x10 joists) 13 risers @ 8.08"

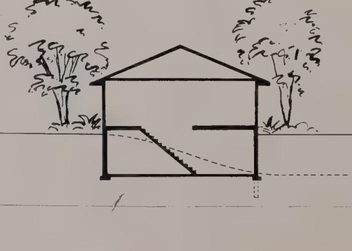
Standards for Main Stairs and Basement Stairs

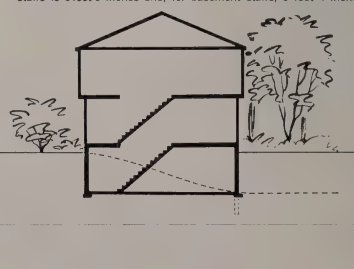
Good stairways require careful planning to eliminate dangers created by poor design. Stairs must be of sound construction and good materials; both features can be advantageously controlled in shop-fabricated component units. Basic stair standards require the minimum number of different units to satisfy the greatest flexible use of variables ordinarily encountered in the basic house types.

Floor-to-floor dimensions, between any two major living levels, are always constant when standard wall heights are used. One standard dimension for 2- by 8-inch upper-floor joists, and a 2-inch larger one for 2- by 10-inch joists are provided. A third standard can be added for 2- by 12-inch joists.

Main-stair standards provide for 14 equal risers and 13 equal treads, except where winders are required. Basement stairs are coordinated in design height with 4-inch modular masonry increments, as shown. Basement stair standards also allow for 2- by 8- and 2- by 10-inch first-floor joists.

Curved, circular and special angular stairway runs are not included in the stairway standards. Minimum clear headroom for main stairs is 6 feet 8 inches and, for basement stairs, 6 feet 4 inches.

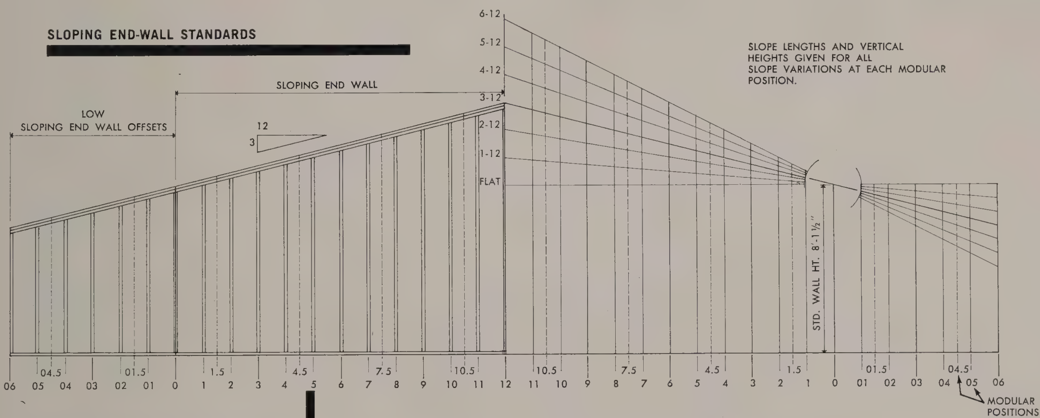




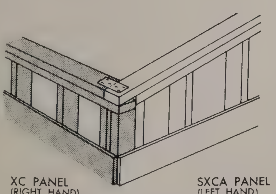
11 Unicom handbook:
Analysis of house forms.

12 Unicom handbook:
Staircases.

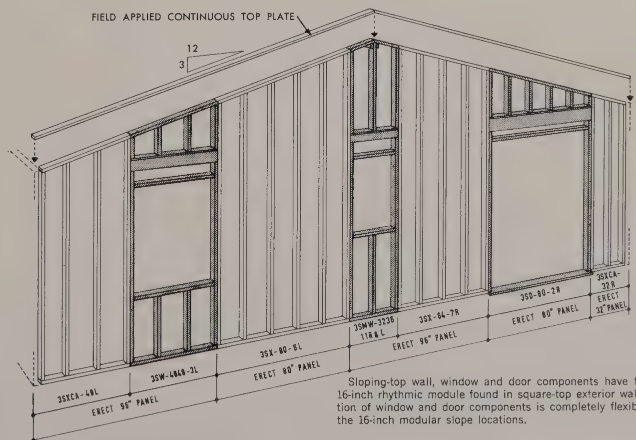
13 Unicom handbook:
Gable walls.



Modular sloping end-wall components, with standard roof slopes, provide a splendid functional designing facility to meet the exacting aesthetic needs of many of the basic house types. Components are fabricated and identified by the positions on the modular slope grid.



Sloping-top corner panels intersect in the same manner as square-top exterior wall corners. Top plate of the sloping end wall overlaps the intersecting square-top corner panel. Front and rear wall plates may have beveled tops for sloping interior ceiling construction. Flat top plates are used for flat ceilings.



Sloping-top wall, window and door components have the same 16-inch rhythmic module found in square-top exterior walls. Location of window and door components is completely flexible within the 16-inch modular slope locations.

for internal load-bearing partitions; the latter not only simplified the site operations but freed the plan arrangement of the house. Another useful development was the production of door units comprising frame, door architraves, and all necessary wedges, screws and ironmongery. In some cases, usually where lifting plant was available on site, manufacturers produced floor panels.

67. Even highly specialised elements such as gable ends and soffit assemblies which were not inherently suitable for repetitive factory production were prefabricated if their complexity was a hindrance to progress on site. The total result of this shift of work from the site to the factory was that it became possible to enclose the house in one day, thus protecting it from the weather and from pilferage and damage.

68. From this description it will be seen that the development of prefabrication did not involve any radical departure from accepted methods of construction; it was merely a gradual change in the location of the assembly process. In this respect the U.S. homebuilding industry has been fortunate in comparison with its British counterpart, because it has not had in a few short years to evolve a new technology while assimilating the processes and effects of industrialisation. On the other hand, it may be argued that this initial advantage may prove to have considerable limitations in the long run since the industry may find it difficult to switch from what are basically developments of craft processes to more sophisticated and essentially industrial methods of production. It does not seem, however, that this potential difficulty can possibly outweigh the tremendous advantages, both in experience and in its public acceptance, already gained through the use of prefabrication on a wide scale.

69. Because of the widely varying circumstances, described in the last chapter, in which American homebuilders operate, all stages in the development of frame construction techniques are currently being used in the United States. There is a steady demand for pre-cut timber: a typical firm specialising in this business will cut, mark and package all the timber and plywood parts for 25 houses a day. This operation adds about 10% to the cost of the timber but can save 15–20% on site, through time saved in selection and cutting, and reduction of losses due to waste and pilferage. Factory assembly is increasing year by year, and it seems, therefore, that its advantages are gaining wider acceptance and becoming more widely applicable. A limited survey carried out in 1961 by the Massachusetts Institute of Technology for the National Association of Home Builders contains the following statistics: builders using prefabricated roof trusses 85%, pre-hung doors 63%, wall-panels 45%, gable ends 32%, partitions 21%, housepackage 13%, floor panels 8%, plumbing trees 8%, and electric wiring 4%.

The following reasons are given for the adoption of prefabricated units, with the underlying assumption that they are at least competitive in price with the construction they replace. Factory assembly leads to a reduction in the labour content of the house, particularly the more expensive site labour, and the sometimes scarce skilled labour. In those areas of the United States which have severe winters with continual hard frost and snow, the use of factory-assembled components extends the duration of the building season; foundations and services for houses to be built in the winter can be prepared in the autumn, the house shell can be erected on a fine day, and work proceed in comfort from that point onwards. In reducing the time required for construction, factory assembly increases the turnover of capital and thus the profitability of the building firm. In addition the use of prefabricated units saves the builder measuring, purchasing and handling individual pieces of material. Finally, the fabrication of the units under controlled conditions produces a product of higher quality, and the simplification of the site operations permits more effective control and higher standards of site workmanship.

Elements of construction

Materials and products

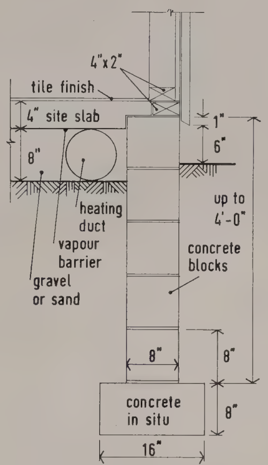
70. Except where described, these are similar to materials and products available in Britain. As with Canadian exports to this country, all American framing timber is dressed. Machines are now available which convert logs directly into dressed sections. Sawn timbers are no longer used in housebuilding except for temporary construction purposes. The planed surfaces give the timbers a high quality appearance, and it is therefore not easy to compare them with the sawn timbers used in this country. The two grades commonly used, Construction and Standard, have higher permissible stress ratings than given in the B.S. Code of Practice 112: 1952, and so it is probable that knots, etc., are fewer and smaller. Since deflection, however, is the main criterion in the design of joists, beams, etc., this higher stress rating does not lead to a significant reduction in the sizes of members required for given spans. Moisture content is carefully specified and maintained: the minimum Federal Housing Administration standards are: for framing timber—19% at the time of installation; for exterior trim and cladding—average 11–13%; for interior trim and flooring—average 10–12%. The last two values apply in the damp southern and coastal areas, and the permitted percentages elsewhere are lower. The reduction of moisture content before delivery of timber to the site is of growing importance as the use of prefabricated components and improved methods of site organisation lead to swifter external enclosure and lining of timber-framed walls and roofs, so that there is no longer time for the timber to dry out on site. Water-repellent preservations such as pentachlorophenol are used to seal the dried timber, and to limit the reabsorption of moisture during its brief exposure on site.

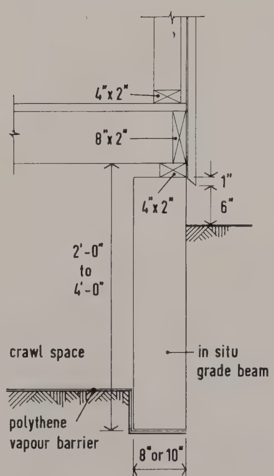
71. Materials delivered to site are well packed and protected, and this has been found to be more satisfactory and less expensive than the cost of replacement or repair of damaged materials. Concrete blocks and bricks are usually stacked and bundled, and are off-loaded with an electrically operated boom, mounted on the lorry. Beams and parcels of plywood sheets are wrapped in bitumenised paper. Doors and windows are enclosed in polythene or even cardboard containers. Where it is still necessary to leave materials in the open, polythene covers are used for protection.

Works below ground floor level

72. *Foundations.* Three alternative types of foundation are used with frame construction—slab, crawl space and basement (Figure 14). Footings are normally taken down below the frost line, and in those parts of the United States where this is 3′ 0″ or more below ground level it is customary to take advantage of the deep footings to provide a semi—or full—basement. Nowadays, because of the development of mechanical equipment and standard steel shuttering, the excavation and construction of basements is simple and economical. The problem of dampness has been overcome, not only through the use of effective waterproofing membranes, but also through the installation of heating and air-conditioning systems, equipped with humidity rectifiers, and used for a large part of the year. Basements are therefore sometimes used in areas where they are not essential for climatic reasons—for split level houses on flat sites, or to provide large, robust and inexpensive spaces below the main house for children's play and storage.

73. Crawl spaces, 18″–24″ deep, originally designed to give adequate ventilation below suspended timber floors, are now sealed and used as plenums for heating and air conditioning systems (Figure 15). In some circumstances this can be more economical than the use of an in situ slab with ducts, and gravel or sand backfill. Basement or foundation walls are constructed in concrete or precast blocks, usually 6″–8″ thick, the former





14 foundations — sections
Site slab and crawl space.

15 foundations — crawl space, with plank floor

Builder: Andrew Place and Company, South Bend, Ind.

The ground below the crawl space is covered with a polythene vapour barrier, and the internal faces of the perimeter beam are lined with mats of glass fibre insulation. The suspended floor above is made of steel beams and three-ply wood planks. It will be used as a heating plenum.

being used generally for basements, and with grade beam construction, for crawl spaces or slabs. In this construction, the footing and wall are replaced by a rectangular beam, often cast directly into a mechanically excavated trench. The use of blocks appears to be restricted to foundation walls on footings at shallow depths, or as an above ground topping to grade beams where these have been constructed without shuttering.

74. *Damp proofing and thermal insulation.* Except in certain arid regions or on well-drained sites a vapour barrier is placed below the slab or crawl space to prevent damage to flooring materials; on sites visited polythene was the material most frequently seen. Basement walls and floors are, of course, also protected. Polystyrene or other insulating board is placed between the slab and the wall, and below the edge of the slab to master the cold bridge.

75. *Concrete slabs.* Screeding is eliminated by giving a smooth manually floated surface to the slab, to which floor finishes can be applied directly.

76. *Suspended floors.* These are usually constructed with 8″ × 2″ or 10″ × 2″ joists at 16″ centres, with a sub-floor of $\frac{1}{2}$″ or $\frac{5}{8}$″ plywood on which is laid a hardwood strip or block, or a resilient sheet or tile floor finish. Because it is cheaper, plywood has almost superseded boards in sub-flooring. As ceilings are not required in crawl spaces and basements, however, supports at 16″ centres are no longer needed, and this has led to the development of floor systems with more widely spaced supports and thicker decks (Figure 15). An advantage of these systems is a reduction in the overall height of basement or crawl space construction. Steel or timber beams are spaced at 4′ 0″ centres and the following decks are available: $1\frac{1}{8}$″ thick plywood in 8′ 0″ × 4′ 0″ sheets; $1\frac{5}{16}$″ three-ply wood planks, 12″ wide and in lengths of 4′ 0″ multiples; 2″ thick timber planks, 4″ and 6″ wide in random lengths. In the last two products the floor finish is integral.

77. *Services.* With crawl space or basement construction, services normally below ground, such as gas and water supply, heating ducts and drainage, are easily run under, and attached to, the suspended floor. In slab construction, these services are laid out within the perimeter foundation wall or beam, at the level of the sand or gravel fill, and the slab is subsequently cast over them. In arid regions, water and gas supply pipes are laid in the fill, but in other areas (Figure 16) they are laid above the vapour barrier and immediately below the slab. (Regrettably, electrical services are usually supplied from overhead cables).

78. *New methods.* The current methods of foundation construction have a number of limitations and there are continual attempts to produce better solutions. So far none of these new methods has gained widespread acceptance, perhaps because they are not yet generally competitive in price, or are rather complicated, or are not yet technically sound enough for general use. Among the experiments the following are of particular interest.

To overcome the problems of winter working, methods using suspended timber floors are being developed which eliminate wet processes and minimise disturbance of the ground:

(*a*) precast prestressed concrete grade beams are supported on circular concrete posts, set in auger-driven holes;

(*b*) concrete blocks, laid on building paper on a shallow gravel

16 foundations — site slab and services

Builder: Levitt and Sons Inc., Levittown, N.J.

The asbestos heating ducts are in the gravel fill below the polythene vapour barrier; copper plumbing pipes are being laid above and the slab will be cast on top.

bed around the perimeter of the building and along internal lines of support, are post-tensioned with galvanised pipe;

(*c*) plywood box beams, treated with preservative, filled with glass fibre insulation, and with the end blocks projecting downwards as posts for 18″–24″, are set in auger-driven holes, subsequently filled with concrete: this forms a continuous perimeter skirt and beam;

(*d*) in a variation of (*c*) without the downstanding posts, the beams become panels supported continuously on a gravel bed;

(*e*) light gauge steel channel beams on the perimeter of the building are supported on square section steel tubes and support steel lattice joists at 4′ 0″ centres, to which plank or plywood floors can be nailed directly.

Methods *a*, *c*, *d* and *e* can also be used where it is desired to eliminate above-ground shuttering for grade beam systems. Another method developed for this purpose is:

(*f*) precast U-shaped formers are set on an in situ footing, while the latter is still wet, then reinforcement is placed in the formers and they are filled with in situ concrete.

Two methods have been developed which eliminate the need for perimeter insulation of concrete slabs:

(*g*) the slab itself consists of 4″ foamed concrete, with a density of 55 lbs. per cubic foot and a U-value of 0·25. It is cast within a perimeter of lightweight cinder blocks;

(*h*) the slab is replaced by 8′ × 4′ panels, 2″ thick, with foamed polystyrene cores and asbestos cement skins. These are laid on a sand bed $1\frac{1}{2}$″ thick, within a perimeter of two 4″ × 2″ cill plates. (*h*) would also be appropriate for winter working.

External wall

79. *Framing*. The main point constructionally is the nationwide use of 4″ × 2″ studs at 16″ centres, and its effect on standardisation and methods of assembly.

Sheathing. This is placed between the framing and cladding and plays an important role in the general stiffness and weather-tightness of the building. Originally boards, sometimes placed diagonally, were used, but now sheet materials, plywood, fibreboard and plasterboard are more popular. The fibreboard is impregnated with bitumen, and, as with plywood, some claddings can be nailed directly to it. The gypsum in the plasterboard is reinforced with glass fibres and treated to render it moisture-resistant, and the 8′ 0″ × 2′ 0″ sheets are enclosed in bitumen-impregnated paper; ends cut on site are caulked. The use of sheet materials for sheathing generally eliminates the need for diagonal bracing. In single-storey construction, F.H.A. requires one 8′ 0″ section or three 4′ 0″ sections of sheathed wall on each elevation—a requirement easily met in detached houses. Another important function of sheathing is the backing given to cladding materials. Air pressure immediately behind the cladding is thus similar to that on the outside, and in this way additional resistance is provided against the penetration of moisture through the customary lapped or rebated cladding joints. As it is very unlikely that cladding and sheathing joints coincide, except where further backed by frame members, any moisture that does get through the cladding disperses between the cladding and sheathing. The sheathing also ensures that the air spaces within the thickness of the wall-framing act as efficient insulators.

80. *Windows.* In the design of windows, the user requirements for opening lights appear to be less exacting than in Britain. The preponderance of single-storey construction means that windows can be cleaned from outside, and in any case less frequent cleaning is necessary because of the absence of industrial pollution in the American suburbs. Large overhangs, which are often a feature of house design because of the need to control the build-up of heat, also give protection from rain. The demands of efficient heating in winter and, in many houses, air-conditioning in summer cause windows to be kept closed: in some fully air-conditioned houses, the only openings provided are external doors. The location and types of opening light provided, therefore, are determined more by aesthetics, lines of sight, and the requirements of production or standardisation. Four types of opening light are commonly in use—sliding, sash, casement, and (Figure 17) projecting. Where screens are provided against insects, the outward opening lights are controlled by a rack and pinion mechanism operated by rotating a handle.

81. Aluminium and timber are the materials primarily used for windows and they are available at similar prices, though there is a wider range in quality and price in aluminium than in timber. Timber sash windows usually have aluminium or p.v.c. runners and steel spring balances (Figure 18). These have excellent weather stripping and draughtproofing devices while permitting a fairly large manufacturing tolerance between frame and opening light (this is useful when frames and sashes are made in different factories). The method of setting the window frame in the wall also appears to be standardised and is shown in Figure 19.

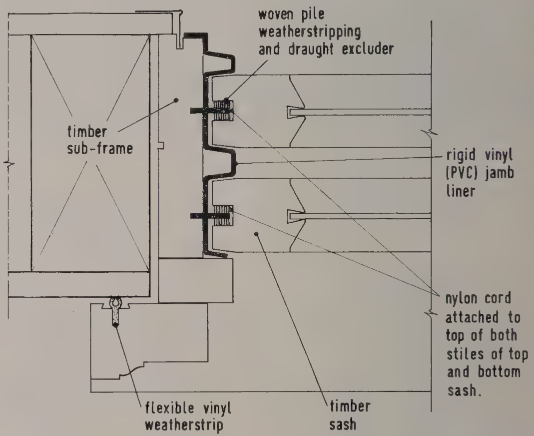
82. *External doors.* These are usually of timber, but a metal-faced door with foamed polystyrene core has been produced. Its advantages are lightness, freedom from warping and a high thermal insulation value. It is more expensive than the timber door, but the manufacturers claim that it is competitive with a double door assembly whose performance it equals. An extremely efficient method of weather stripping has been developed, based on the type of seal used for refrigerator doors. This consists of a strip of soft magnetised steel contained within a hollow section of p.v.c. The p.v.c. is fixed to the frame and on closing the door the strip is attracted to the metal door itself or to a metal strip applied to a timber door.

83. *Cladding.* Unlike English brick construction, in which the structure and external finish are the same material, in U.S. frame construction the external finish, whether wood siding (cladding) or masonry veneer, is superimposed on the sheathed framework of the house, forming a complete outer casing interrupted only by window and door openings. Sidings, originally of horizontal or vertical timber boards, or shingles, are now available in many other materials—plywood, aluminium, steel, asbestos, hardboard and rigid vinyl (Figure 20). In appearance the new products are generally similar to the original ones. Improved watercheck details have been devised for the horizontal sidings made of thin materials, i.e. metals and plastics. Secret fixing methods have been developed for metal, plywood and hardboard sidings, so that long-lasting finishes can be applied in the factory; they also provide automatic spacing for successive rows of siding. The hardboard is a specially developed medium density type which is used mainly in the drier areas of the United States and appears to be dimensionally stable.

84. The dimensional stability of sheet materials permits their use in whole sheet form, thus reducing the joints to a few vertical ones. The products are available with a great variety of textures and profiles, which aim to give a pleasing appearance, to overcome surface irregularities, to mask accidental site damage, and to incorporate the vertical jointing system.

85. Masonry veneer takes the form of 3″ or 4½″ brick, or stone of appropriate thickness, tied across a 1″ cavity to the wood

17 projecting window
Manufacturer: Andersen Corporation, Bayport, Minn.



18 sash window, with plastic liner
Manufacturer: Andersen Corporation, Bayport, Minn.

frame; bitumenised building paper is used as sheathing. There are also special stone veneers with a thickness of only 1″ which are fixed to the wood frame with stainless steel clips. Stucco is used in some of the warmer regions of the United States, and is applied to chicken wire, backed with building paper, and attached to the wood frame.

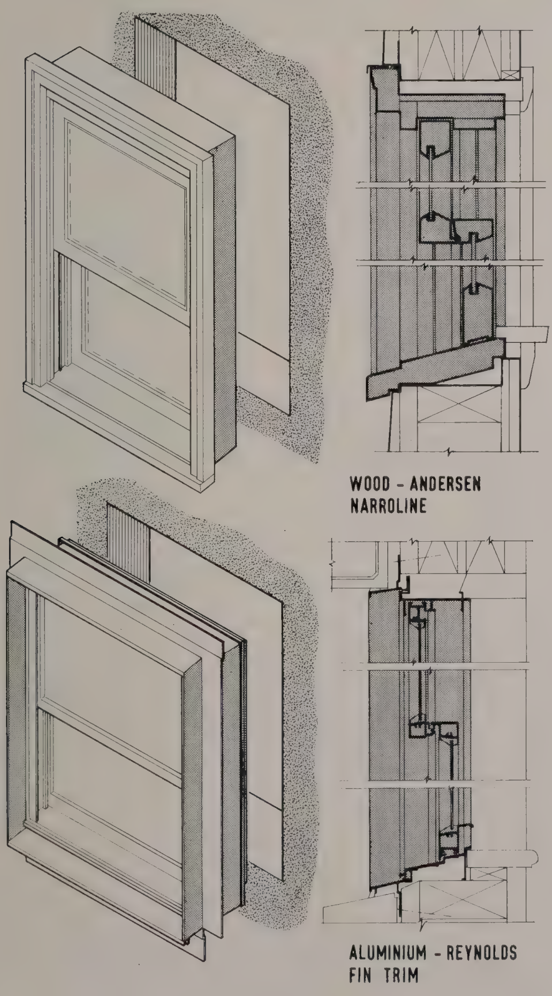
86. Masonry, hardwood shingles, and asbestos shingles have the advantage of being maintenance-free, but other wood products require repainting every five years or so, though the cleaner, less corrosive American atmosphere often allows an extension of this period. There is a certain traditional acceptance in the United States of the need to repaint houses which works against the development of maintenance-free surfaces. The opportunity to change the external colour of the house is considered by some to be as important as the opportunity to redecorate internally. In mitigation it is pointed out that the painting of cladding compared with that of windows and doors, which is common to all houses, is straightforward and therefore relatively inexpensive. Nevertheless, the new developments producing better surfaces for painting, long-lasting paints and other permanent finishes are generally welcome, provided that they do not substantially increase the initial cost of the house.

87. Hardboard and metals provide better surfaces for painting than wood or plywood; hardboard is usually factory-primed, and the metal sidings have a stoved-on enamel finish, estimated to last 15 to 20 years. Plywood manufacturers recommend that plywood should be treated with creosote or other preservative stains; it is inevitable that small checks will appear on the surface of the material and this is not consistent with a smooth paint finish. To emphasise the essential nature of the plywood surface, striated and roughsawn finishes are being produced. For painting, an exterior plywood with the panel faces overlaid with a resin-impregnated paper surface is now available; although more than doubling the initial cost of the plywood, its cost in use must be attractive, as the material is gaining widespread acceptance. The preservative stains, and some of the best alkyd and latex paints now available, if properly applied to suitable wood surfaces, can have a life of up to ten years. It is hoped that the new thermosetting acrylic paints now being developed will have a life of up to 20 years. The maximum life of a natural transparent timber finish is considered to be three years.

88. Another promising line of development for cladding finishes is in coatings of plastic films: polyvinyl-fluoride, polyvinyl-chloride and polyester are all under investigation. One firm markets a plywood siding with a polyvinyl-fluoride coating and guarantees the product for 15 years. This period corresponds with the length of time that the film has already been in existence, and accelerated weathering tests show that its actual life is likely to be considerably longer. Current work is concerned more with developing suitable long-lasting adhesives and inexpensive substrates for the plastic films. Synthetic rubber coatings are also being used on pilot schemes. Solid vinyl cladding promises to be extremely durable, but as with all plastics sufficient time has not yet elapsed to show what its actual life will be. Also at the development stage is a sand aggregate finish embedded in an epoxy coating on plywood.

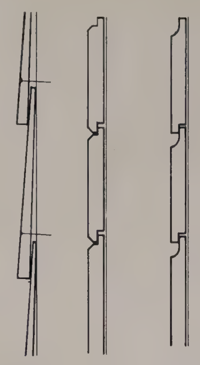
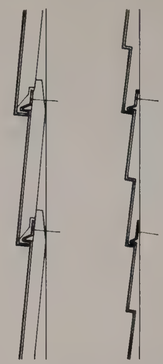
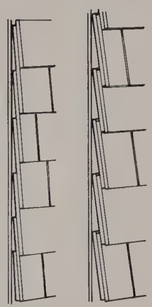
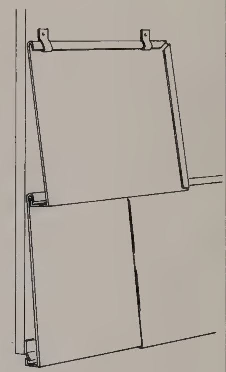
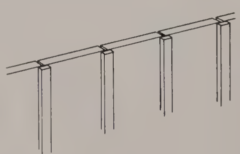
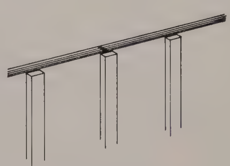
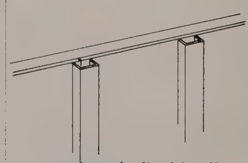
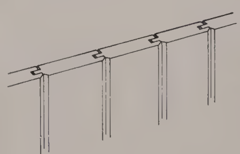
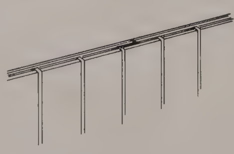
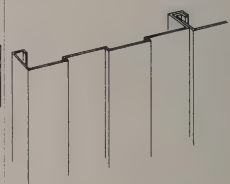
89. As a general indication, the cost, fixed, of wood, plywood, asbestos and hardboard claddings is of the order of 26/– to 33/– per sq. yd.; stucco and softwood plywood cost less than 26/–; plastic films add around 6/– per sq. yd. to the unfinished material; aluminium sidings range from 26/– to 44/– and brick 50/– to 80/– per sq. yd.

90. *Insulation.* 2″ and 3″ glass fibre insulation is commonly used, either in the form of friction-fit batts, i.e. unwrapped blankets of material which fit precisely into the spaces between studs and top and bottom plates; or of paper-faced rolls, of inter-stud

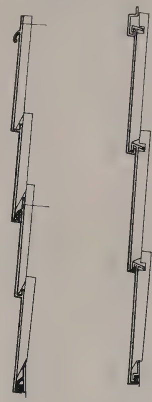
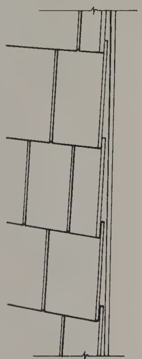
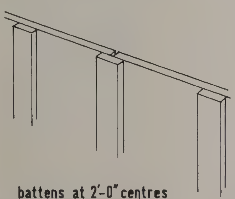
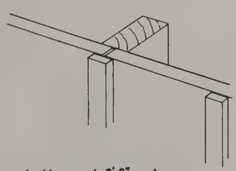
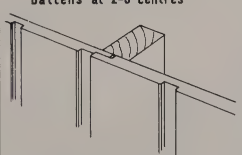
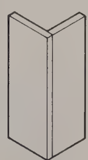
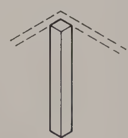
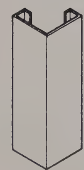


19 method of setting windows in wall

The window has a rebate or flange which fits against and is fixed to the face of the sheathing, thus giving excellent alignment and weatherproofing.

	WOOD	PLYWOOD	ALUMINIUM	STEEL
HORIZONTAL SIDING	 bevel V-rustic drop		 with or without insulated backing	
LENGTHS	random	8'-0" & 12'-0"	12'-6" 12'-3$^{11}/_{16}$"	12'-6"
FINISH	paint or stain	PF-15 Tedlar PVF Film-Dupont	vinyl	stoved enamel paint
PRODUCER	—	United States Plywood	Johns-Manville	United States Steel
SHINGLES	 single double			
SIZE	16", 18", 24", x random widths		36" x 12"	
FINISH	natural		stoved enamel or natural	
PRODUCER	—		Reynolds Metals Company	
VERTICAL SIDING board and battens	 battens at 4"-12"	 battens at 2'-0" centres	 cover channels fixed to clips at 16" centres	
boards		 grooves at 2" or 4" centres		
WIDTHS	4" to 12"	4'-0"	4'-0" & 1'-0"	1'-4"
FINISH	paint	preservative stain	pre-painted	stoved enamel paint
PRODUCER	—	American Plywood Association	Reynolds Metals Co./Johns Manville	Armco Steel Corporation

20 range of cladding materials

ASBESTOS	HARDBOARD	VINYL	CORNER DETAILS
			 external corner  re-entrant corner
9'-4"	12'-0"	—	corner pieces produced in appropriate materials and finish for all types of horizontal siding
factory primed	factory finished	self finish	
Johns-Manville	Masonite Corporation	Bird & Son,Inc. or Monsanto	
			as above
9" x 32"			
vertical grooving			
Certain-Teed Products Corp.			
 battens at 2'-0" centres	 battens at 2'-0" centres  grooves at 4" or 8" centres		  external corner re-entrant corner  
4'-0"	4'-0"		corner pieces produced in appropriate materials and profiles for all types of vertical siding.
factory primed	factory primed		
Johns-Manville	Masonite Corporation		

21 roof truss

Manufacturer: Continental Homes Inc., Boones Mill, Virginia.

The operatives are positioning the connector plates, before passing the truss through a press.

22 asphalt shingles

Builder: Fox and Jacobs, Dallas, Texas.

width, in which the paper projects from each side of the roll to form a flange which can be nailed or stapled to the studs. The advantages of standard wall framing are clearly apparent here.

91. *Vapour barrier.* This is provided by a foil backing to the paper cover of the glass fibre insulation or by foil-backed plasterboard.

92. *Lining.* See internal walls (paragraph 100).

Roof

93. *Roof framing.* As already described in paragraph 62, the roof framing is now usually assembled into trusses made of 4″ × 2″ members fixed together with rectangular galvanised steel connector plates which assist or replace the process of gang nailing (Figure 21). Some of the plates have simple circular holes and are nailed to the timber members; more frequently, however, the plates have been punched out with a rectangular pattern of projecting teeth which themselves engage the timber. Timber tension members are sometimes replaced by galvanised steel hangers with connector plates at each end. The advantages of the metal plates over the plywood ones which were previously used are twofold; firstly, they obviate glueing, and the setting out and fixing of rows of nails; and secondly, because of their negligible thickness, there is no wasted space between trusses during transport.

94. *Sheathing* is usually $\frac{3}{8}$″ plywood, and aluminium H clips with edges tapered to a minimum thickness are used on unsupported edges instead of timber noggings.

95. *Finish* is generally of asphalt shingles; these are rectangular sheets made up of layers of felt, 36″ × 12″, impregnated with bitumen and topped with mineral granules. They are laid, as shown in Figure 22, in overlapping rows with an exposure of 5″. Except on roofs with very steep pitches a felt underlay is provided. The top part of the shingle is nailed to the sheathing and the lower edge is sealed to the underlying shingle by a dab of asphalt pre-applied in the factory. The exposed part of the shingle has cuts in it, so that, when finished, the roof appears to be covered with a surface of small rectangles, similar in appearance to, but smoother and more precise than, a slate roof. The advantages of this system over the built-up sheet roofings are pleasantness of scale and freedom of movement under differing thermal conditions between the roof covering and sheathing; no hot bitumen is required and each man can work independently, an advantage on a sloping surface. Wood and asbestos shingles are sometimes used and are nailed to plywood sheathing or to battens. On roofs of very shallow pitch, built-up felt roofing of not less than three layers, topped by chippings or gravel, is used. For appearance the chippings are sometimes graded in size to include a few very large pieces, 1″ or 2″ across.

Roof finishes of plastic are being used experimentally. Polyvinyl-fluoride has been bonded to asbestos-faced felt, and applied to the roof in the conventional manner, the joints being sealed with finishing tape. Polyvinyl-fluoride and synthetic rubber have also been applied to plywood sidings and used as roof coverings. With the latter product an ingenious method has been used of cutting the plywood right through to the synthetic rubber coating so that the long edges of the siding can be folded back to form an interlocking waterproof joint; this is not yet sufficiently developed for general use. Various factory- and site-applied spray and brush plastic coatings have also been tried. None of these methods as yet offers sufficient advantage over conventional methods for it to be adopted on a wide scale.

Sheet steel and aluminium roofing materials are also available, but they are only competitive with other finishes if used with purlin and not in roof truss construction. Purlin construction differs so much from the standard roof truss construction that these self-supporting materials will probably be used only as elements in completely different systems of construction.

96. *Insulation.* 2″ or 3″ glass fibre batts are customary, placed between ceiling joists.

97. *Ceiling.* $\frac{1}{2}$″ plasterboard as for the lining to external walls.

Upper floors

98. See suspended floors (paragraph 76).

Internal walls

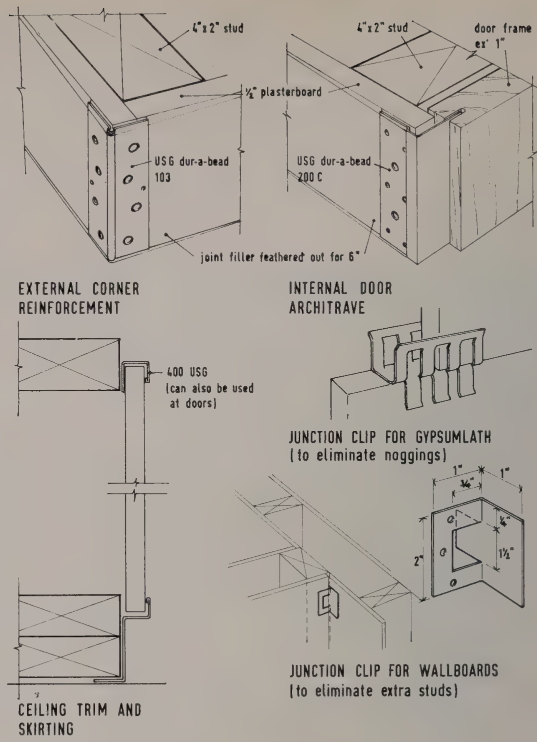
99. *Partitions.* Framing is as for external walls. Some prefabricated partition units of two skins of plasterboard with hollow cores of paper or wood products are available but are not widely used. This may be because U.S. methods of work scheduling (see section on site assembly and operations) make it preferable to separate the trades, and the use of prefabricated units would involve combined work by electricians and partition erectors.

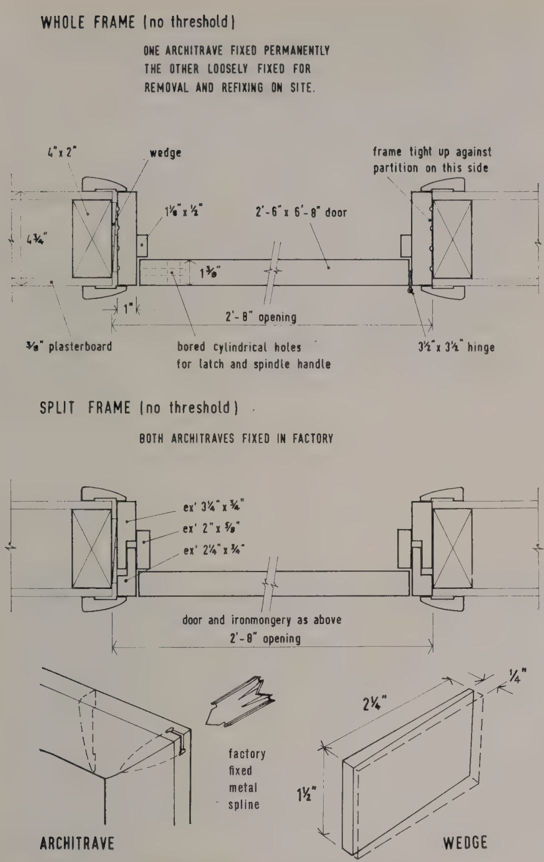
100. *Lining.* The internal lining is generally of plasterboard with taped and filled joints, and a very high standard of finish is customary. This follows some years of experiment and experience so that the techniques are now well understood (see paragraph 147). Metal angles are used at all corners to ensure a firm and robust edge, and special clips are available which can be used instead of noggings at wall junctions, and, if ceilings are to be fixed at the same time as wall finishes, at the junctions of ceilings and walls (Figure 23). Two special types of plasterboard are also used internally. One is a water-resistant type for use in bathrooms, and its surface paper is especially suitable as a base for ceramic tiles. The other is a vinyl-faced board, available in a wide range of colours and patterns; this is fixed to the stud framing, with adhesives, or with nails with coloured heads to match the vinyl.

Plywood wall panelling is also used to a limited extent, and its cost, fixed, is competitive with plasterboard. The plywood is $\frac{1}{4}$″ thick, and has V grooves vertically, apparently at random intervals, though a groove is provided every 16″ so that fixing pins do not appear on the surface of the panel. A wire pusher has been developed which forces high-strength wire from a coil, through the plywood into the framing and cuts it off flush with the surface. The wire is lost in the pattern of the board and needs no filling. The finish is either a hardwood veneer treated with a plastic seal, or a lacquered paper printed photographically with wood grain.

101. *Internal doors.* The widespread use of pre-hung doors is notable. The standard door is 6′ 8″ × 2′ 6″ × $1\frac{3}{8}$″ thick and the frame is made from 1″ nominal material. Each door has three hinges—$3\frac{1}{2}$″ loose-pin wrought steel with $\frac{5}{8}$″ radii at the corners, and with a plate finish—which are set in rebates formed with a router. The lock or latch set fits into two circular holes, drilled out at right angles to one another. There are two types of frame —whole frame with architrave fixed to one side only in the factory, and split frame with both architraves factory-fixed (Figure 24). For transport, the assembly is stiffened by nailing through the frame into the edge of the door, cardboard packers being inserted between frame and door at these points. Wedges for packing out between frame and opening are supplied with the door unit, one part of the wedge being sometimes pre-fixed to the door frame, so that only the second part has to be driven on site. Other items not fixed in the factory, the door handle, the second architrave, and possibly a door stop, are also supplied with the door unit. The rough opening into which the frame fits is 6′ 10″ × 2′ 8″ in factory-made partition units; an extra $\frac{1}{2}$″ may be allowed for site-built partitions.

102. *Party walls.* As most houses built are detached, there is relatively little experience in the use of party walls in lightweight construction. In the Minimum Property Standards, in addition to the general requirement for a fire resistance of two hours, there is a specific clause requiring the inclusion of at least 4″ of





masonry; this is at present a basic factor in the design of party walls. The masonry is usually concrete block, 6″ or 8″ thick, with plasterboard, attached to firring pieces, on both sides; or 4″ concrete block if attached to 4″ × 2″ stud framing on both sides—plasterboard is then applied to the framing. No particular consideration is given to the sound insulation of these walls.

103. However, much experimental work on sound insulation for party walls in lightweight structures has been carried out,* and results approximating to House Party Wall Grade have been obtained. These constructions use staggered timber studs, 4″ × 2″ or 3″ × 2″ at 16″ centres; nailed to the studs is either a ½″ rigid resin-bonded glass fibre insulation board or a ½″ fibreboard; ⅝″ plasterboard is bonded to the backing board with adhesive, in such a way that through joints are minimised. Similar constructions using steel studs give slightly lower values.

* The experiments are described in the following: Building Materials and Structures Report 144 of the National Bureau of Standards, U.S. Department of Commerce, Washington, D.C.; *Solutions to noise control problems in the construction of houses, apartments, motels and hotels.* Owens-Corning Fibreglass Corporation, Toledo, Ohio; *Wallboard and partition systems.* Johns-Manville Corporation, New York 16.

23 accessories for plasterboard (far left)

Manufacturers: U.S. Gypsum and National Gypsum Company.

24 door and frame units (bottom left)

Builder: Del E. Webb, Phoenix, Arizona.

25 door and frame units (left)

26 internal finishes (below)

Builder: Eichler, San Francisco, Cal.

Veneered plywood is applied over the plasterboard lining.

Heating and air-conditioning

104. Ducted warm air systems are most frequently used because the installation costs are generally less than those of systems in which hot water or steam is used to effect the heat exchange, and because the ducts can also be used for air conditioning. The main fuels are gas and oil, both of which occur naturally within the United States. The ducts are usually made of galvanised steel sheet, though there is some experimental use of polyester resin reinforced with glass fibres, and they are run in the roof space, above a false ceiling in circulation areas or below a suspended floor, crawl space or basement. Below slabs, asbestos cement ducts are buried in sand or gravel fill. With crawl spaces, ducts can be omitted and the whole space used as a plenum for heat distribution. An important feature of the heating systems is the humidity rectifier which improves comfort conditions by relating humidity to temperature.

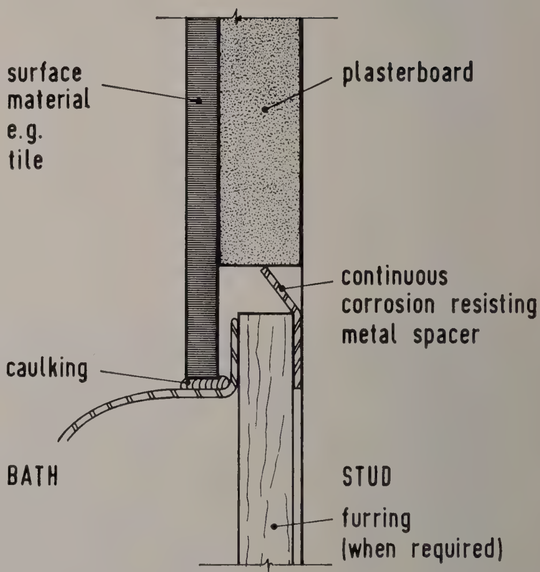
Sanitary fittings and plumbing

105. Basins are usually of vitreous china and are set in counters of polyester resin reinforced with glass fibres, or of powdered stone bonded with epoxy resin. The counters are moulded to give a splashback at the junction with the wall and a lip on the other edges; integral basins of moulded reinforced plastic are also available. Pressed steel baths have an integral side panel and on the remaining sides an upstanding lip provides a flashing for waterproofing the junction with the wall (Figure 27). Baths, with head-height wall linings, made of polyester resin reinforced with glass fibres, and shower stalls are being tried out on an experimental basis. The installed cost is said to be comparable with that of conventional fittings and ceramic tile surrounds. Sinks are of porcelain-enamelled steel, and integral draining boards are available. As dish-washing machines become more prevalent, the need for draining boards diminishes and sinks are frequently set directly into work surfaces. Stainless steel sinks are less commonly used.

106. Plumbing—supply drainage and vent pipes—is commonly all in copper; plastics for piping are still at an experimental stage. Where the house plan is so arranged that the plumbing in kitchen and bathrooms can be adjacent, the vertical pipework is accommodated in a wall framework of 8″ × 2″ studs or between two 4″ × 2″ frames, 4″ apart. A few firms manufacture plumbing walls (Figure 30). However, there is some resistance at present on the part of the plumbing unions and of the building code inspectors to the introduction of factory-installed plumbing. For this reason, prototype bathrooms, made completely of moulded polyester resins reinforced with glass fibres, have not been further developed, since factory installation of the plumbing is essential for economic viability. There have also been various attempts to develop heart units, containing all the bathroom, kitchen and heating equipment, but these have also been held back because of the factory-installed plumbing. In addition, the weight of these units necessitates the use of mechanical lifting equipment on site, and the introduction of this equipment for the sole purpose of installing the heart unit is uneconomical. In houses which have been designed to be erected with the use of mechanical equipment, and where the manufacturer is his own erector, conditions are more favourable for heart units (see paragraph 189).

Electrics

107. Accessories have been designed to facilitate the fixing of socket outlets, battenholders and other equipment to timber studs and joists without carpenter-fixed noggings (Figures 28 and 29). Hollow plastic skirtings have also been developed for the multiple provision of socket outlets.

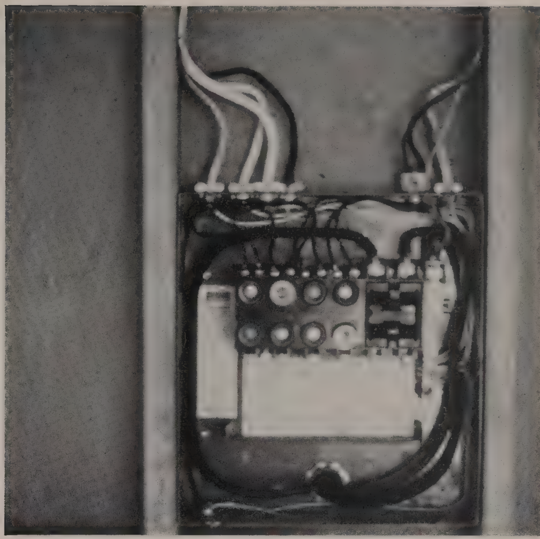
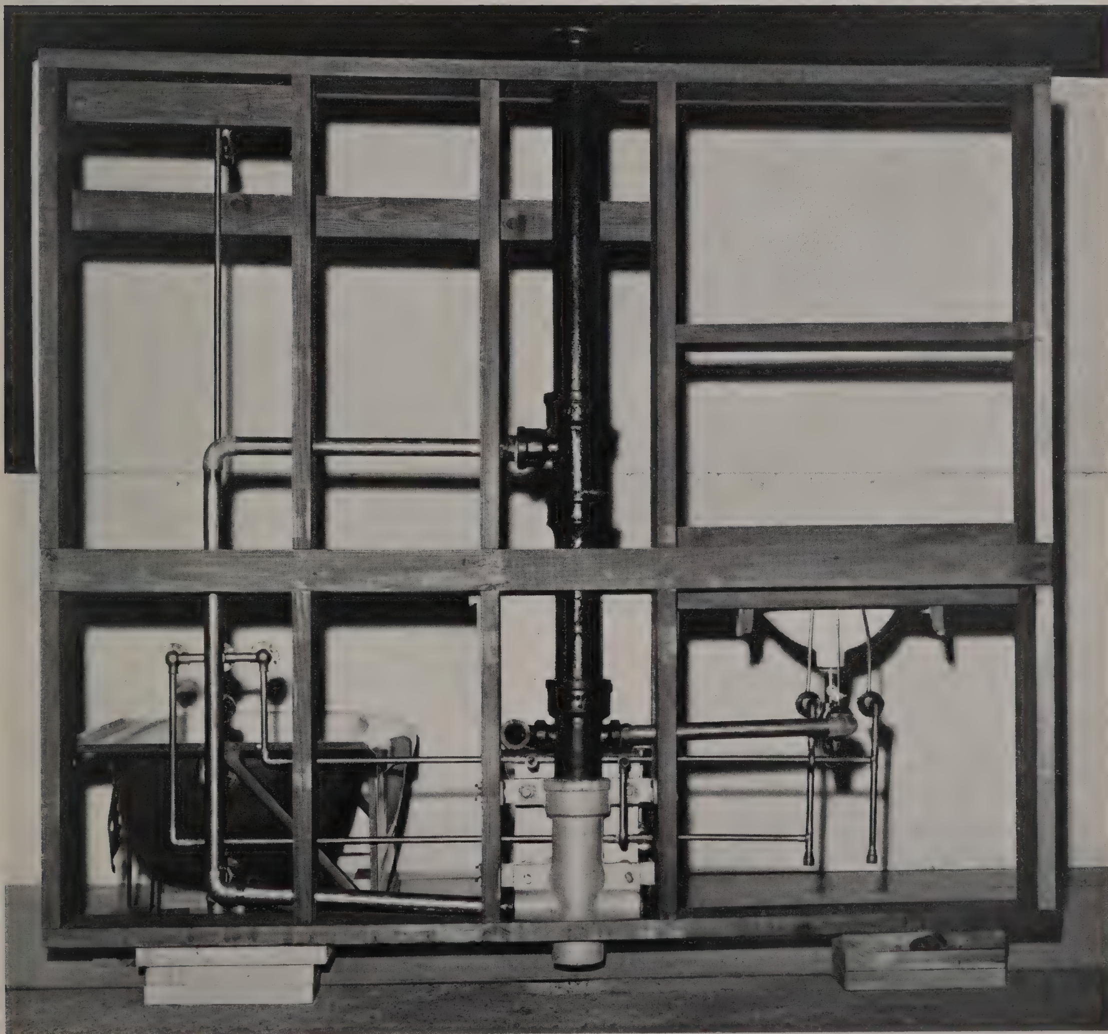


27 bath — junction with wall (above)
The bath is designed to fit against the wall, and not to be freestanding.

28 electrical installation: battenholder (right)
The battenholder is supplied with an expanding strut, which allows it to be fixed directly to the roof truss members.

29 electrical installation: control panel (far right)
The panel fits precisely between two studs at 16″ centres.

30 plumbing wall (bottom right)
Manufacturer: Kingsberry Homes Inc., Chamblee, Ga.

Fabrication by home manufacturers

108. Operations in home manufacturers' factories* consist of the assembly of timber members, sheet materials and sundry other parts into house components; their collection, together with other materials, components and equipment, into packages for individual houses; and the loading of these sets of diverse units on to trailers for delivery to the building site.

109. There is very little cutting, and still less moulding, of the timber sections. For example, all the framing members in wall panels, including those surrounding openings, are unprofiled rectangular sections, and are connected to each other with butted and nailed joints. Openings are weathered by the profile of the window and door units (Figure 19). These units, of course, are made of moulded sections, but they will probably have been bought in, either as complete units or in knock-down form, from specialist producers. The most complicated sawing operation in home manufacturers' factories is the cutting of timber for roof trusses. The lengths are critical, the end cuts may have to be angled, and bird's mouth notches may also be required. The machine used for this purpose—a development of the double-ended tenoner—houses two circular saws, the distance between them being variable and calibrated; the saws can also be inclined, and additional cutters added to produce notches.

110. In layout the factories consist of a number of assembly lines or stations for wall panels, roof trusses, door and frame units, gable ends, etc., with storage and sub-assembly bays adjacent to them. Storage is also required for other items such as cookers, rolls of insulation, heating equipment, packets of roofing shingles, and cans of paint, on which no work will be carried out in the factory itself; in this respect, home manufacturers act as builders' merchants. Storage areas frequently equal fabrication areas in size.

111. The factories are used solely to produce house packages and some have been built for this purpose. There is thus a permanence about the factory layout which is in striking contrast to the fluidity of arrangement required in the more usual general purpose joinery workshop. Changes in home manufacturers' layout are made only as part of a planned programme of improvement or expansion.

112. The factories are set up to produce individual houses because an order may be received for one house, or for a batch of houses containing different models, or variations of the same model. Because manufacturers expect to deliver to builders within a fortnight of receiving their orders, it is not possible to make up large batches for delivery. Even a builder producing 100–150 houses a year would only amass an order of four or five houses in two weeks, and it is in any case unlikely that all the houses would be identical in every respect; the more items the manufacturer supplies the greater the likelihood of variation. Finally, every manufacturer deals with many builders, and if the sites are to be kept supplied, their orders must be dovetailed into one another.

113. Most manufacturers work from a range of models. A recent *House and Home* survey gave the following analysis:

manufacturers making not less than 25 designs 33%; 25–50 designs 21%; 50–100 designs 14%; 100 or more designs 17%; unlimited designs 15%.

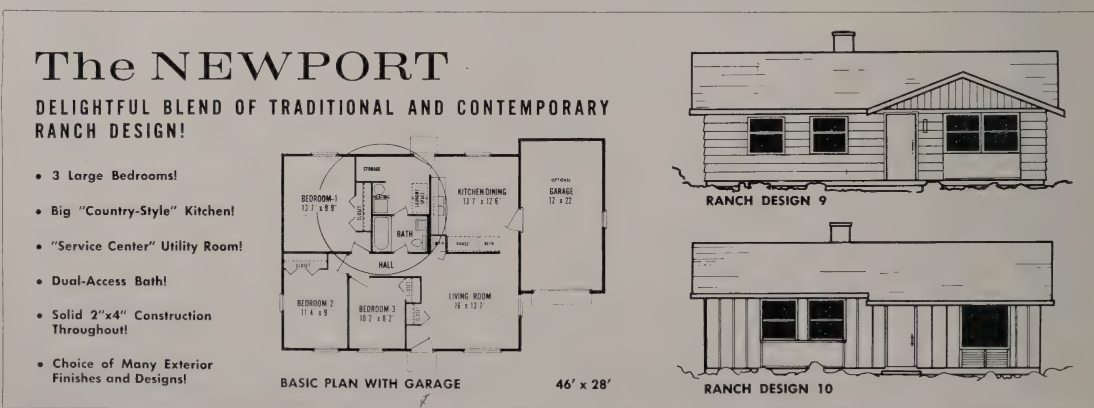
The average range consists of 55 models—those manufacturers offering an unlimited range are probably operating as described in paragraph 28.

114. From time to time manufacturers will add new models reflecting new trends to their range, and others not selling well will be discontinued. The models will cover the various house forms—one- and two-storey, split level, bi-level and split foyer—and a wide range of accommodation and areas. Some models may be closely related—within the same shell two large bedrooms may become three smaller ones, or the relationship between dining room, kitchen and living room be changed by varying doors and partitions; a garage or a basement may be added. Other options apply to the whole range of models—the type and finish of the cladding, the pitch of the roof, the colour of the asphalt shingles, and the general trim and accessories which give the houses the appearance of different architectural styles. Manufacturers may also be willing to vary their models for individual builders—more willing, of course, if business is slack than if it is booming. In addition, a builder need not take all the items offered by the manufacturer—he may opt to buy separately such items as roofing shingles or heating equipment, he may propose not to provide a refrigerator, or he may prefer to construct his partitions in situ.

115. In order to ensure that the builder gets the house his customer wants, manufacturers have pro forma orders which require the builder to list the model number and to choose from the options available (Figure 31). This order initiates the manufacture and collection of the components for the house package.

116. The larger the manufacturer's volume the more chance he will have of grouping the orders to give repetition on the assembly lines; such grouping was obviously not possible for the smallest firm visited—output two houses a day—but was of considerable importance to the largest which was producing 35 houses a day and had a peak potential of 50. The builder's

* The material in this section is based on visits to the following firms: Acorn Structures Inc., Concord, Mass.; Andrew Place and Co., South Bend, Ind.; A.B.C. Package Co., Healdsburg, Cal.; Great Lakes Homes Inc., Sheboygan Falls, Wis.; Holiday Homes, Fort Worth, Texas; Kingsberry Homes Inc., Chamblee, Ga.; National Homes, Lafayette, Ind.; Pease Woodworking Co., Hamilton, Ohio; Sterling Custom Homes, Fond du Lac, Wis.



GREAT LAKES HOMES, INC. | Quote No. | Production No.

Date 10/7/63 — Send Quote To

xxxxx New American Classics — Address

Builder — City & State

Plan Description: Newport - 28'x34' #1 — Drywall - Plaster — Basement — Crawl — Slab

Living Room on Left — Living Room on Right — Basement Height

Lower level ext. walls No — Insulation No
Lower level windows No
Lower level storms & screens No
Lower level int. walls No — Doors No
Lower level trim - Base ☐No Shoe ☐No
1x2 Wall furring ☐No Ledge cap - 1x6 ☐, 1x8 ☐, No ☒
Lower level siding No
Floor joist size None
Deck No — Block for single floor No
Adjustable steel posts No — Length
Wood basement beam (stock only) No
Mudsill (or sill plate) by No
House sheathing ½ - ¾ - None
Gable sheathing ½ - ¾ - None
Garage sheathing ½ - ¾ - None
Common wall sheathing ½ - ¾ - None
Sill (or box) sheathing ——
Garage size No
O. H. door size No — By
Garage mudsill by No
House siding Horizontal masonite
Gable siding Horizontal masonite
Garage siding No
Siding variations No

Roof - Hip ☐ - Gable ☒ — Roof Pitch 4½/12
Trusses 2x4 — Size 24"o.c.
Ceiling joist size —— — Rafter size ——
Main overhang Per Elev. — Gable overhang Per Elev.
Build gable out for brick — Roof sheathing 3/8" ply. w/clips
Shingle type 235# — Color
No. lineal ft. metal drip edge Yes
Window header size Std.
Window Type Wood D.H.
No. Lites Per plan
Storms & Screens Alum. Comb.
Picture window description Per plan

Window sizes as shown —
Window sizes by Great Lakes Yes
Glass Sliding Doors No — Size — Glass Type
No. pair window shutters Per plan
Door shutters size No
Trim - Pine — Oak — Mahogany
2¼" Base ☒ — 3¼" Base and base shoe ☐
Type of heating by bldr. —
Bath room base trim by GLH ☒ — by Bldr. ☐
Doors - Birch — Oak — Mahogany
Sliding doors No
Bifold doors Metal - Classic style
Number of Pocket doors No
Front doors Per plan (Side lights) no
Rear doors Per plan
House to garage door No
Garage service door No
Hang exterior doors Yes
Comb. door - Type Alum. — Number 2

Med. cabinets numbers #7462
10" Ceiling fan, Kitchen - 3 speed - Damper No
4" bath fan — 8" wall fan - kitchen No
Bath accessories Yes
Shelf material Metal
Special front lock No
Sills ☒ Oak — ☐ Pine
Metal threshold Yes — Oak threshold No
Nail package Yes — Weatherstrip Applied
Wall insulation 2" — Garage insulation No
Ceiling insulation 2"

Stairs	Basement	Main
Treads	No	No
Risers	No	No
Stringers	No	No

Number of handrails No — Floor stripping - (1x2 - 16" o.c.) No
Oak floors in No
⅝" Underlay in No
Variations No

BELOW WILL NOT BE QUOTED WITHOUT DETAIL

Kitchen cabinets No — Kohler sink No
Counter Top No — Color
Vanity cabinets No — Vanity top No
End Splash No — Hood Model No
Oven Model No — Burner Model No
Primed exterior trim Yes — Flower box Per plan
Plaster grounds by GLH — Yes ☐ — No ☒
Mas. chim. ☐ (Gas-Oil) Metal Chimney by Bldr. ☒ by GLH ☐
Planters No — Divider No
~~½ metal windows — ¼" round sweet bend only~~ ☐
~~— 1x4, casing, sill & stool ☐ — full trim ☐~~
~~— 1x4 jambs~~
Additional 2x4's for - Drop Ceiling ☒ - Duct Work ☐No

MISCELLANEOUS

Options:
Elev. #7
Elev. #8
Elev. #9
Elev. #10
Elev. #11
Elev. #12
12'x22' garage
22'x22' garage
Deck material-crawl
Deck material-base. -includes
Basement stair material

Not Included: Flooring Nails - Sheetrock W.I.Rail
Other: Paneling, pre-finishing of doors

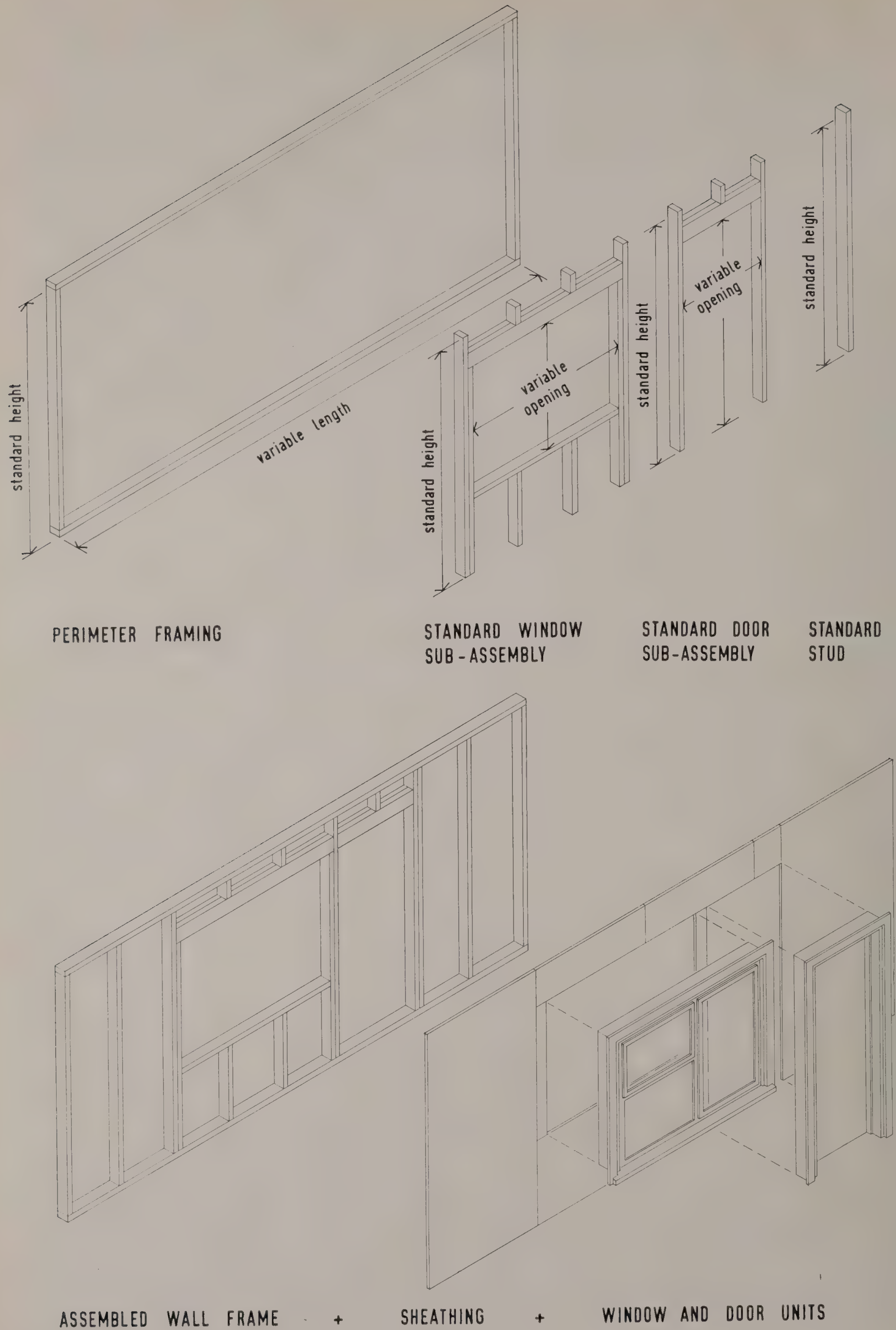
NET F.O.B. JOB SITE + Tax

OPTIONS	DEDUCT
Col. #2	
Col. #3	
Col. #4	
Col. #5	
#6	

31 order form for manufactured home

Manufacturer: Great Lakes Homes Inc., Sheboygan Falls, Wis.

The manufacturer's representative will go through this form with the builder to ensure that full details are given to the factory. The circle on the plan opposite refers to details which show alternative arrangements for houses with basements.



32 manufacture of external wall panels: component parts of framing

order is translated into a set of instructions which, in their simplest form, are a set of house drawings with the options pencilled on, and, at their most sophisticated, a set of production tickets giving the house order number, the item number of the component, its part number, the quantity and a short description. When production tickets are used, every item, right down to shutter boards and posts, and boxes of nails, becomes a component and has a ticket. The number of tickets for each house amounts to several hundred, but they are produced automatically by pressing the relatively few buttons needed to identify the various options from the range available. When processed by a computer, the tickets produce valuable feedback information for the sales, purchasing and accounting departments.

117. As many components and parts as possible are produced on a batch or mass production basis. Door-and-frame units, windows, wall studs, roof truss members, will be manufactured continuously, or in batches for a number of houses. Only when the product is bulky or expensive, or when the number of possible arrangements of standard components within an element becomes so great that the date of probable use of the element is remote or even unpredictable, are these elements produced on a job basis.

118. The instructions for the day's production are sent to the foremen in charge of the assembly lines and stations, and of the warehousing departments. Where the instructions consist of drawings, they are self-evident; where production tickets are used, the component drawings are available at the assembly lines. A firm of medium or small output will have one line each for wall panels, roof trusses, and possibly partitions, and stations for gable end assemblies, and door-and-frame units. The firm visited, which was producing 35 houses a day, had 11 assembly lines in use.

Wall panels

119. The methods employed on the wall panel assembly line are of special interest, because of the range of products made from a few standard components. From the manufacturing point of view, the wall panel consists of the following parts: perimeter framing, window and door framing sub-assemblies, intermediate studs, sheathing, windows, cladding and, exceptionally, insulation, wiring and lining (Figures 32 and 10). These parts are put together on the assembly line at a number of stations, from material stacked adjacent to the line, the panel being pushed from station to station on rollers let into the sides of the line. The line is 8′ 0″ wide (the height of the panel) and may be over 100 feet long. The panels themselves are usually a maximum of 12′ 0″ long, though if the cladding is light or not to be applied, and if the windows are not too heavy, 16′ 0″ lengths are sometimes produced. On sites where it is proposed to use mechanical lifting equipment, panels may be made up to 40′ 0″ in length and are usually manufactured at one station, on a jig table.

120. At the first station on the assembly line (Figure 33), the perimeter framing, the door and window framing sub-assemblies, and intermediate studs are assembled. The vertical studs in the perimeter frame are, of course, of standard height, but the top and bottom plates vary in length with the overall length of the panel. The plates are selected by one of two methods, which subsequently governs the method of positioning the framing. In operations where there is great standardisation of the panel lengths, for example, five lengths at 2′ 0″ increments between 8′ 0″ and 16′ 0″, the plates are selected from the stock of pre-cut lengths adjacent to the assembly line. The two plates and the two studs forming the four pieces of the perimeter framing are then laid on the table of the assembly station, and are held in position by blocks attached to the table. The next step is to place in

33 manufacture of external wall panels: assembly

Manufacturer: National Homes, Lafayette, Ind.

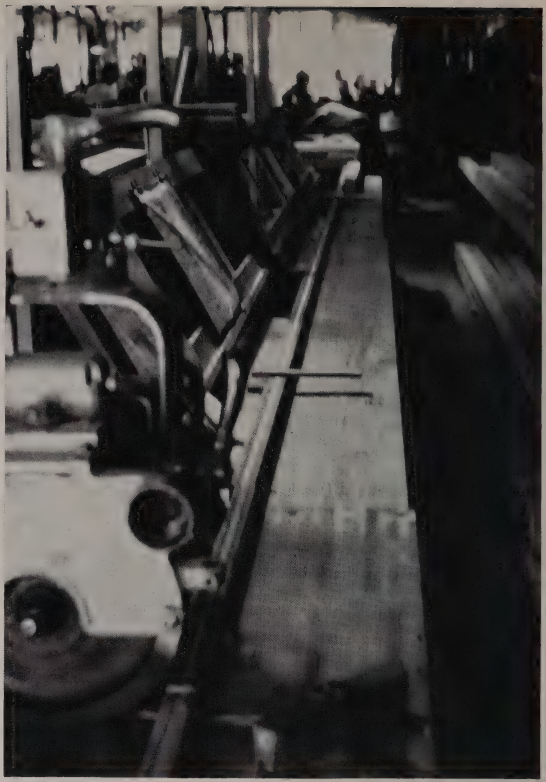
The wall framing has been assembled and is about to move on to the next station. The operatives have already selected the top and bottom plates for the next panel and have placed them temporarily on the completed frame. To the left can be seen the foreman's desk with the book of component drawings, and the production tickets, one roll per house, are suspended on a bar above. In the background are the stocks of materials cut to length.

position any window or door framing sub-assemblies. These are manufactured in bays adjacent to the assembly line, and consist of the framing which surrounds the window itself, and of all other vertical members required between the window and the top and bottom plates. These sub-assemblies are positioned within the perimeter frame by measurement or by blocks attached to the table. The remaining assembly task at this station is to insert the intermediate studs at 16″ centres, and these are positioned, again by blocks. The assembly is then held firmly by clamps attached to the sides of the table and all the parts nailed together. Manufacturers usually work to tolerances of $\pm \frac{1}{16}''$ on frame member positions.

121. Where there is less standardisation of panel lengths, the plates are selected from a stock of random lengths and the two pieces are laid on a bench fitted with an inset measure (Figure 34). By inspection of the drawings, the overall length of the plates, and the positions of the sub-assemblies and studs, can be swiftly marked. The drawings used may consist of the ordinary house drawings, or standard component drawings. Two new ideas were encountered; in the first, the elevational drawing of each wall was replaced by a line, along which there was a series of letters indicating stud, double stud, window sub-assembly, etc., these positions being dimensioned. By this means all the cutting and marking-out information for the wall panels of a whole house can be contained on a single A4 sheet. The second innovation used a plastic tape, stored on a film reel; the tape was fully marked to actual size with the plate lengths, stud positions, etc., required for a house, and the firm was thus able to carry the information for its whole range of models on some 40 tapes. The advantage was that by simply working along from one end of the tape to the other, the marker-out could be assured that all the plates necessary for the specified house would be provided. With this method, using fully marked top and bottom plates, blocking pieces are not required on the assembly table, and the lifting device under the rollers, otherwise necessary to allow the frame to clear the blocks before being pushed to the next station, can be eliminated.

122. A further refinement of the framing process was seen in one factory visited. Here the intermediate studs were not inserted at the first station, but as the framework was carried along the assembly line mechanically and at a controlled speed, it passed under a machine which automatically dropped a stud into place at 16″ centres, and nailed it to the plates.

123. For those manufacturers applying the wall lining in the factory, this is carried out at the next station. The lining is applied before the cladding and windows, because its flat surface can be fully supported on the assembly table while the latter are being fixed; this would not be possible in reverse order with the uneven outer surface of the panel in position. First, the electric switch-boxes and socket outlets are fixed and wiring is threaded through holes in the studs, suitably long tails being left for connection to fittings in adjacent panels. Alternatively, when the wiring and accessories are to be installed on site, vertical draw wires may be secured by nails fixed in rebates in the top and bottom plates. Next, a glue-dispensing machine is run over the faces of the studs, and 8′ × 4′ sheets of the plasterboard or plywood lining placed in position, and secured by nails at top and bottom and possibly along the vertical edges: the panel may be run through a revolving press to secure effective adhesion. A routing machine, suspended overhead on a light framework, and operated by a man on each side of the assembly line, is then manipulated around door and window openings in order to cut away the lining; and if the panel is not a multiple of 4′ 0″ in overall length the surplus part of the edge lining sheet is removed from the end. On leaving this station the panel passes through a device which turns it over before reaching the next station. If insulation is to be installed, it is glued to the lining or stapled to the studs.



124. The advantages of applying the plasterboard or plywood lining in the factory are that the sheets can be accurately positioned and secured mainly with adhesives, thus producing a high quality finish for which a minimum amount of filling and jointing is required on site. There is a saving in the total labour and a reduction in the amount of site labour required. These advantages have to be set against the possibility of damage in transit and erection, but manufacturers consider that with reasonable experience this is negligible. Two further objections remain, however, and it is these which have prevented widespread use of lined panels. With the plasterboard lining it is not possible to eliminate site jointing completely (see, however, paragraph 185), and it has been found in practice that unless it is possible to omit a trade completely, the full economic advantage will not be realised. Secondly, local building inspectors may insist on the site inspection of panel interiors and on site wiring.

125. The sheathing is nailed to the outer surfaces of the framework. There are automatic nailing machines available which will insert nails along all framing members at specified centres as the panel passes along the assembly line. Openings are sometimes routed out as for the lining, but as sheathing materials are more expensive than lining materials, and as the joints do not have to be made good in the same way, the 8′ 0″ × 4′ 0″ sheets are usually pre-cut into smaller rectangles and placed round the openings.

126. A polythene flashing is dressed round the window openings and the window dropped into position. As shown in Figure 19, the window frame has an outer flange or lip and this is fastened through the sheathing to the frame. The windows, primed timber or aluminium, are already glazed; they may have been purchased in this form or they may have been put together from knock-down parts in a sub-assembly bay. Figure 19 also shows that

the timber window head (and jambs) are made from a number of small rectangular sections. These sections are stitched together in an autonailer (Figure 35). The advantages of this method are that smaller sections are more easily obtainable than large ones, and, being generally rectangular, make good use of the material; moreover, the moisture content of small sections can be more quickly and easily reduced, and being rectangular, and not deeply profiled, as well as restrained by adjacent members, the sections are not subject to twisting and warping. External doors are not usually installed in the factory because of their weight, and to avoid damage on site when other components are carried into the building.

127. Finally, the cladding is applied. With cladding made from 8′ 0″ high sheets, joints are reduced to a minimum, since a cover strip or simple overlap can be used at the vertical junctions between panels. Horizontal cladding presents a more complicated problem as the appearance of vertical cover strips is not popular, and it is difficult to ensure effective weatherproofness if the outer surfaces of the cladding materials do not form one continuously plane surface along the joint between panels. The solution most often used is to leave off short lengths of the cladding adjacent to the vertical edges of the panels and for the remainder of the cladding to be fixed on site. This has the advantage of covering the junction of the panels, but it is an intricate operation, since, in order to avoid a through vertical joint in lapped cladding, successive courses of the factory-fixed cladding are stopped off at varying distances (Figure 49) from the edges of the panel. Unless panels are large and vertical joints thus few in number, it may be preferable to fix all the horizontal cladding on site. Some benefit can be obtained by careful positioning of the panel joints in an elevation. One firm designs its panels so that wherever possible the junctions occur some 4″ from tall openings such as doors or windows with a low cill. The panel frames for each elevation are produced in sequence

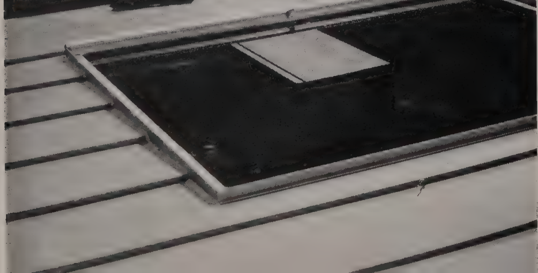
34 manufacture of external wall panels: setting out

Manufacturer: Sterling Custom Homes, Fond du Lac, Wis.

The house plans are clipped to the board above the bench, and the tee-square used to mark the timber is on the measure below them. In the foreground is the circular saw, and to the right the stock of wall plates.

35 autonailer

The machine holds small pieces of timber firmly together, and as the timber is moved through the machine forces steel fasteners through them at set intervals. The fasteners are cut lengths of thick wire just visible on the right, drawn from a continuous coil, and both ends are bent over in the stitching process.



36 manufacture of roof trusses

Manufacturer: Sterling Custom Homes, Fond du Lac, Wis.

37 manufacture of external wall panels: fixing cladding

Manufacturer: Kingsberry Homes Inc., Chamblee, Ga.

38 manufacture of external wall panels: caulking windows

Manufacturer: Andrew Place and Company, South Bend, Ind.

39 manufacture of wall panels: transfer to loading bay

Manufacturer: National Homes, Lafayette, Ind.

and are laid together when the cladding is to be applied. The cladding is laid over the panel joints wherever such an overlap will bring the cladding up against a door or window frame in the adjacent panel, but is, of course, fixed to only one panel. The panels are transported with the cladding projecting, and all that remains to be done on site at these points is some nailing and caulking.

128. Generally, the cladding is nailed to the sheathing or framework in the conventional manner: in some cases power-driven tee-nails or staples are used. Great accuracy in location and coursing and in fitting round openings is possible, and the caulking of joints under these conditions is reliable (Figures 37 and 38). One firm has developed a method of fixing profiled aluminium sheeting to the sheathing with adhesives. The panel then passes through a revolving press which has a rebated cylinder to match the projections on the sheeting. Pop rivets are used to fix aluminium flashings and cover strips to the sheeting, both in the factory and on the site.

129. At the end of the assembly line, the panel is hoisted into a vertical position and transferred to the loading bay, either on a trolley or by an overhead carrier system (Figure 39). The latter method avoids double handling and keeps the panels in their correct house sequence for loading.

Roof components

130. *Roof trusses.* Three types of machine for assembling roof trusses were seen. Essentially, the process involves holding the pre-cut timber members in place, positioning the metal connectors on both sides and nailing them, and then applying pressure to drive the connectors into the timber. The first machine (Figure 36) consists of an adjustable metal rack raised into a position just off the vertical, which can be arranged to accommodate trusses of various pitches and spans; the rack is so designed that the junction points of the truss members are accessible from both sides, and thus the connectors can be applied simultaneously. The rack then swings down into a horizontal position, the truss is deposited on a set of rollers, and is pushed through a roller press. In the second machine, blocks are attached to a horizontal wooden table, the timber members and connectors applied to one side. The truss is then reversed on to another table adjacent to the press, the connectors applied to the second side, and the truss pushed through the press (Figure 21). In a refinement of this machine, the wooden table has adjustable metal blocks with sinkings for the connectors, and the table top itself is on rollers and can be run through the press, so that connectors can be applied to both sides of the truss without reversal and no intermediate handling of the truss is necessary. The third machine consists of steel "bollards" secured to and running in grooves in the floor to allow location at the junction points of a variety of trusses. At the head of each "bollard" is a "mouth" into which the two connector plates and the ends of the timber members can be placed. When the assembly is complete, electrically controlled pressure is applied simultaneously to all the junctions. The time taken to assemble roof trusses by these methods is between two-and-a-half and four man minutes per truss.

131. *Gable ends.* These are the triangular wall sections occurring below pitched roofs on end walls. They are similar in construction to the external wall panels but their non-rectangular shape and the variable pitch make assembly line production difficult. In order to ensure conformity with the other wall panels, and to speed progress on site, it is preferable for them to be made in the factory. Because of their complexity and the relatively small numbers required they are manufactured on a single jig table.

132. *Gable end assemblies.* These form the roof overhangs at gable ends. They are often fairly complicated and accuracy is necessary to obtain a good appearance. As with the gable ends it is therefore more satisfactory to produce them in the factory.

Floor components

133. The production of floor panels (Figure 40) is rather unusual because of the small proportion of two-storey houses, and because mechanical equipment is necessary to place them in position on site. The only operations normally carried out in the factory are the cutting to length of the joists, if these are not bought in precise lengths, and possibly the grooving of the trimmers into which they fit. For some floor plans it may also be necessary to cut some special sizes of plywood sub-flooring from standard sheets (this applies also to the roof sheathing). Beams, used internally where partition support for joists is not available, are made from two 8″ × 2″'s or 10″ × 2″'s stitched together with an autonailer, similar to that shown in Figure 35.

Partitions

134. *Panels.* The framing and lining are put together on an assembly line, as for the external wall panels.

135. *Door and frame units.* The great quantity required has made possible the development of elaborate machinery for the production of the units; the advantages are high precision and the minimal use of labour. The most advanced machine seen (Figure 42) consists of a framework into which the door and two jambs are inserted. Routing and drilling machines are permanently attached to the framework, and, on starting the machine, rebates for the hinges, and holes for the lock or latch and for the handle spindle are formed simultaneously in both door and jambs. The hinges are fixed to door and jamb before the parts are withdrawn from the machine. The lock or latch is inserted and the striking plate fixed. The door and jamb, the remaining jamb and the top of the frame are then placed in another jig, where the frame members are fixed together, and packers inserted between door and frame. Meanwhile, the three parts of each of the two sets of architraves have been assembled. The parts are held in a jig and a metal spline inserted at each corner as shown in Figure 24. One set of architraves is then fixed firmly to the door with a stapling machine which has a stop to give the correct offset on the frame. The other set is lightly pinned as it has to be removed while the door frame is inserted in the site opening. Where doors and frames are painted or sealed in the factory, this is done before the assembly of the parts.

Loading

136. During assembly, everything needed for the house—the components, the bundles of primed trim, the cartons of accessories and the packaged equipment—will have the house serial number marked on or a copy of the production ticket attached. As all the parts converge on the loading bays, the foreman in charge of loading is able to check them against his list and the trailer is then loaded in such a way that the parts are available in the order required on site (Figure 41). The trailers are 8′ 0″ wide and 40′ 0″ long, though some manufacturers use shorter ones down to 24′ 0″ in length. The trailers are either open-topped with 9′ 0″ high sides and double doors at the back, or consist of a flat bed with central vertical metal framework so that the overhead system can carry components right on to the trailer. Tarpaulin covers are used in transit. Most manufacturers stack their components vertically. External wall panels with cladding attached are held away from each other by cross struts or bands which are nailed into the tops of the panels. One trailer can accommodate the components for a house up to approximately 1,100 sq. ft. in area. If the house is larger than this, a second delivery is made to the site possibly several days after the first, with a smaller lorry carrying the internal trim and equipment. The complete set of components for a house varies in weight from 12,000 to 25,000 lbs.

40 manufacture of floor panels

Manufacturer: Home Building Contractors Inc., Sedelia, Missouri.

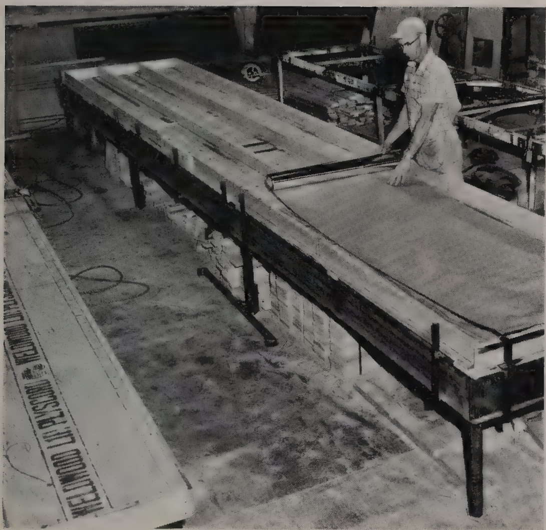
41 manufactured homes: loading of trailer

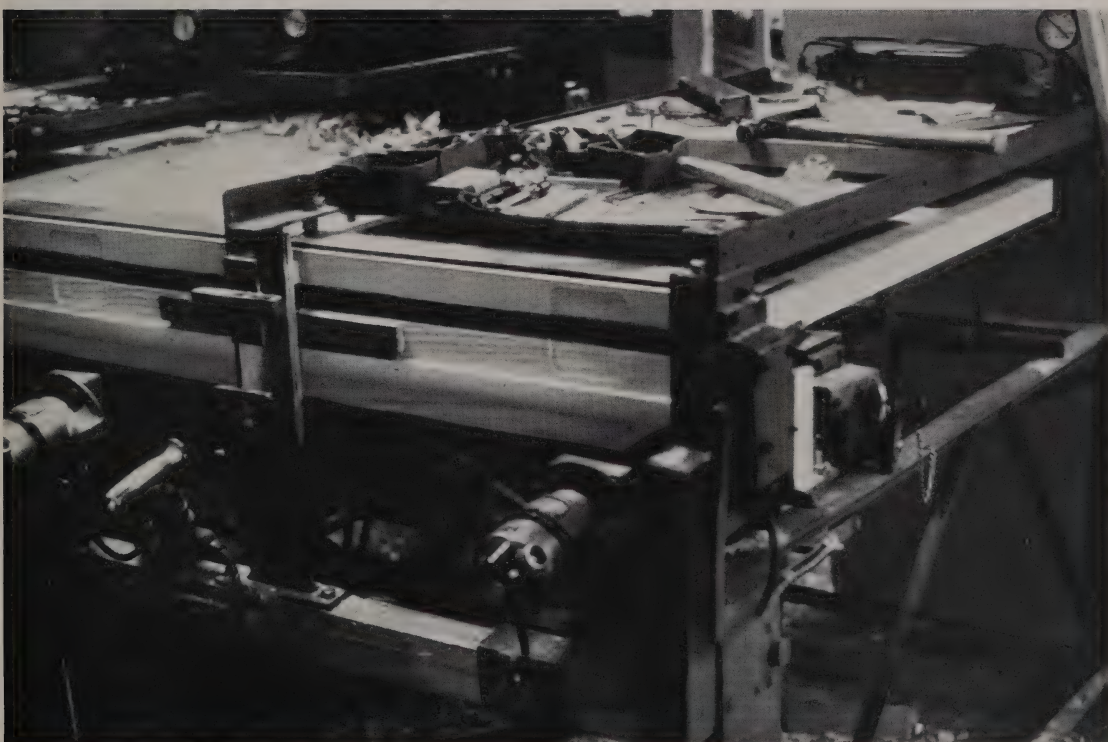
Manufacturer: Kingsberry Homes Inc., Chamblee, Ga.

42 manufacture of door and frame units

Manufacturer: Great Lakes Homes Inc., Sheboygan Falls, Wis.

The framework holds the door and both jambs, and all routing and drilling is carried out simultaneously.





Site operations and assembly*

137. The choices available to builders in methods of purchase and in the organisation of site operations have been discussed in paragraphs 17–19 and 69.

Works below ground floor level

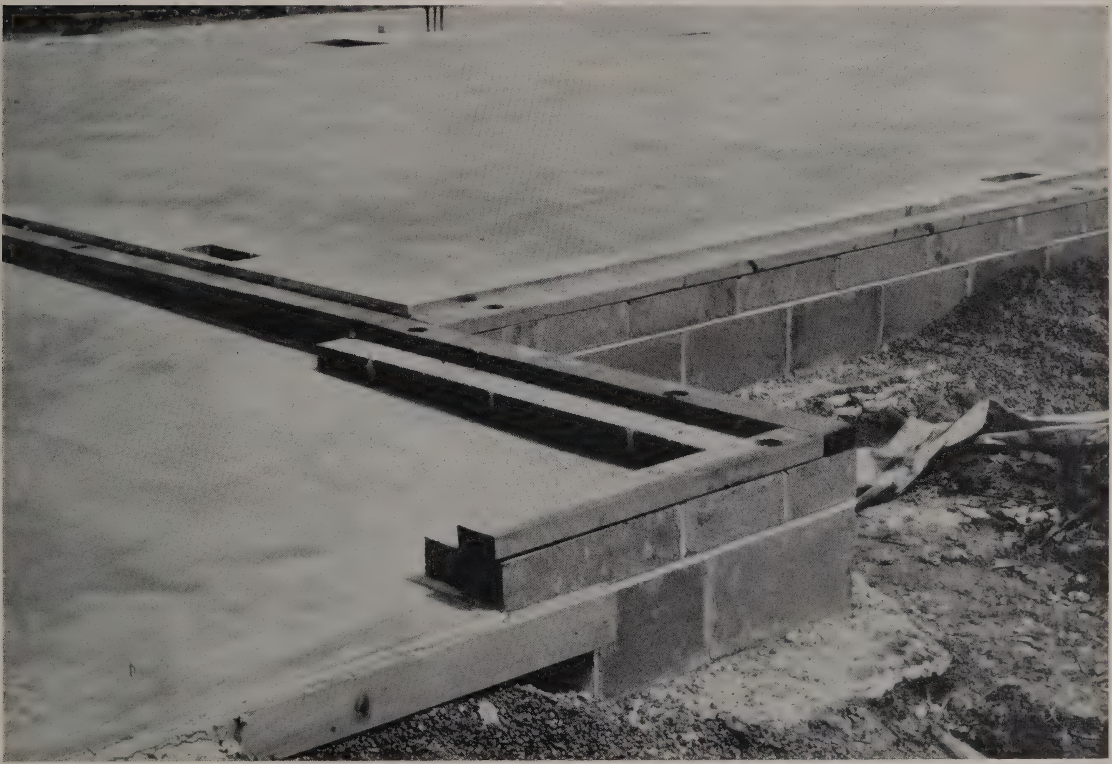
138. Not less than eight working days before commencing the superstructure, the builder will start on the work of clearing the site, setting out the building, preparing the foundations and installing the services below ground. If the site is within an estate which the builder is developing, the topsoil will probably have been removed, the land graded, and the roads partially constructed at an earlier stage. Trenches for footings or grade beams, for deep services within the building, and for those outside are then excavated with mechanical equipment (Figure 43). In some cases it is possible to cast the grade beam directly into the excavated trench; with this method excavation is reduced to a minimum, there is no backfill, and the ground immediately adjacent to the building remains relatively firm (Figure 15).

139. Asbestos cement heating ducts are laid on the excavated ground within the building and buried in a bed of sand or gravel (Figure 44). Water and gas supply pipes will be laid either in the

* The material in this section is based on visits to the following firms: Andrew Place and Co., South Bend, Ind.; Del E. Webb, Phoenix, Ariz.; Fox and Jacobs, Dallas, Texas; R. J. Hunter Inc., San Jose, Cal.; Levitt and Sons Inc., Trenton, Pa.; Maverick Homes, San Antonio, Texas; National Homes, Lafayette, Ind.; Pauly and Co., Cincinnati, Ohio; Sterling Custom Homes, Fond du Lac, Wis.

sand or gravel bed or on top of a polythene vapour barrier laid over the bed (Figure 16). The service pipes are sometimes continued up above the slab to the level of the baths, basins, etc., so that there is no further work for the plumber until the fitting and connection of the equipment (Figure 45). If it is not practical to make an immediate connection to the services in the road, the required length of pipe is coiled up in a starter trench immediately outside the building.

140. Foundation beams and slabs are formed with ready-mixed concrete (Figure 46) and a surface smooth enough for thin tile floor finishes is obtained with a manually operated float.



43 site operations: excavation of foundation trench (top far left)
A reinforced concrete grade beam will be cast directly into this trench.

44 site operations: heating services below the site slab (top left)
Builder: Levitt and Sons, Inc., Levittown, N.J.
The brick box forms a base and plenum for a down-flow heater.

45 site operations: gas and water services below the site slab (bottom left)
Builder: Del E. Webb, Phoenix, Arizona.
Because of the dryness of the climate, it is possible to lay the water and gas supply pipes in the gravel fill.

46 site operations: site slab (above)
Builder: G. and J. Price, Lafayette, Ind.

Erection of house shell

141. For the builder using a manufactured house package, the key day in his organisation is the one on which the package is delivered. The timing of his preliminary operations will have been worked back from this day, and subsequent operations will be dependent on it. On this day the largest gang will be working on the house, and delay in starting or completing their erection work can be expensive, as demurrage charges on the trailer average 52/– per hour. At the beginning of the day following the arrival of the house package, a gang of six or eight men will start on the erection of the shell of the house (Figures 10 and 47). All the components are nailed to one another. By the end of the day, the gang will have put up the external wall panels, the roof trusses and sheathing, and possibly some partitions. If the house is two-storey or has a basement or crawl space, the suspended floors will also have been constructed. The roof will be covered with the under layer of felt, and as the sheathing and glazing of the external walls has already been carried out in the factory, the shell, with the exception of the opening for the entrance door, is now complete. The next operation is to carry the remainder of the components into the house and then the entrance door unit is fixed; the house is then both weathertight and pilferproof. If the house is of average size or smaller, and progress has been good, further work will be done that day. Cladding will be fixed, if this has not already been done in the factory; the asphalt shingles will be laid and more partitions erected.

142. The advantages of the manufactured house package in simplifying site operations are obvious; the provision of bulk storage, sorting out and double handling are eliminated; components and materials not fixed immediately are stored under excellent conditions and are ready to hand when needed; above all, there is the certainty that all the parts required for the house have been delivered.

143. Most builders place the components in position by hand, and they maintain that the cost of using a crane would be prohibitive. The few builders who do use mechanical equipment of course take the opposite view (Figure 48). The total cost of the labour for erecting the shell is of the order of £100, so that quite a high percentage saving in labour has to be made to pay for the hire of a crane. The use of a crane eliminates a few joints in the external wall because larger factory-made panels can be erected; it may save some complex patching of horizontal cladding: in houses with suspended floors, large floor panels can be used instead of individual joists and sheathing; the lifting of single roof trusses is also avoided, as several can be bundled and hoisted together. The type of crane favoured is a lorry-mounted telescopic boom. A typical crane of this type has a maximum capacity of five tons at the lorry, and can be extended for a distance of 50 feet, with a capacity in this position of one-and-a-half tons; its maximum elevation is 65°. This crane can place in position from a single location all the components for a house. One builder manufacturing his own wall panels in lengths up to 40 feet uses a fork-lift truck with boom to take the panels off the lorry and move them into position on the house; the fork-lift truck is also used for lifting roof trusses (Figure 49).

144. The technique of individual house packaging has been developed for detached houses, but it is now being applied to terrace houses, as can be seen in Figure 47. Each trailer still contains the components for one house only, and the construction of the terraces proceeds house by house, each succeeding house being started one day after its neighbour.

47 erection of house shell

Builder: Gateway Corporation, Indianapolis, Ind.

The panel is moved with its bottom edge at the top in order to avoid damage to the projecting cladding.

48 erection of house shell: use of crane

Builder: Hanover Highland Homes, Hanover Park, Ill.

By using a crane, it is possible to handle prefabricated floor panels.

49 erection of house shell: use of fork-lift truck

Builder: Andrew Place and Co., South Bend, Indiana.

FOUNDATION SCHEDULE			
DAY	OPERATION	DATE	CONTRACTOR OR SUB.
1	stake building and grade off	Aug' 2	contractor
2	trench foundation and pour concrete footing	" 3	contractor
3	" " " " " "	" 4	"
4	lay block foundation walls clean up all materials	" 5	Marsh contractor
5	fix wall plates, first rough plumbing, sewers, water services, etc.	" 8	contractor White.
6	lay gravel and grade for slab	" 9	contractor
7	pour slab, stoops, walks and driveways	" 10	contractor

ERECTION SCHEDULE	UNIT No. 80653	DELIVERY DATE	August 12th 1964
DAY	OPERATION	DATE	CONTRACTOR OR SUB.
1	erect ground floor panels and partitions erect first floor joists and deck panels erect roof trusses and sheathing	Aug' 12	contractor
2	lay asphalt shingles erect first floor partitions	" 15	Carter contractor
3	fix aluminium siding complete exterior trim	" 16	contractor
4	fix rough plumbing, incl. bath paint exterior	" 17	White A.B. Painting Co.
5	fix rough electrics	" 18	XY Electrics.
6	fix rough heating install insulation deliver plasterboard	" 19	Bell contractor
7	apply plasterboard	" 22	Brown
8	tape and fill plasterboard joints	" 23	"
9	fill plasterboard joints - 2nd. coat	" 24	"
10	dry plasterboard joints	" 25	"
11	fill plasterboard joints - 3rd. coat	" 26	"
12	sand plasterboard joints	" 29	"
13	fix interior trim	" 30	contractor
14	paint interior	31 — Sept 1 thru 14 *	A.B. Painting Co.
15	set kitchen cabinets finish electrics		contractor XY Electrics.
16	clean floors	2 or 15	contractor
17	lay floor tiles	3 or 16	contractor.
18	fix ceramic tiles, internal doors, cupboard doors erect fence, carry out miscellaneous repairs	6 or 19	contractor.
19	finish plumbing finish heating	7 or 20	White Bell
20	clean house, inspect house	8 or 21	contractor
21	finish work reported by inspectors	9 or 22	contractor

* these dates apply if owner does own painting

50 site operation schedule: individual house

This is a typical schedule used by a site foreman to programme site operations for houses built from a manufactured house package. The opportunity afforded to customers to paint their houses has been discussed in paragraph 15.

Completion of the house interior

145. *Programming*. Following the erection of the house shell, the remainder of the house is erected in 21 or 22 working days. A typical erection schedule is shown in Figure 50. The schedule given is for a builder using a manufactured house package. The sequence is similar for conventional builders though the framing operations occupy more time. It will be noted that the schedule is arranged so that only one trade at a time is in the house and that each trade is allowed a day or half a day to complete its work. This means that a gang of sufficient size must be put on the job to enable it to get through in that time. The gang of six or eight on the shell has already been mentioned; other typical gangs seen were two plumbers fixing the rough plumbing, two or three plasterers fixing the plasterboard, four taping and filling the joints, and one joiner fixing kitchen cabinets. Of course, the task may not take the gang all day, in which case they may go on to a second house, or if they are sub-contractors they may transfer to another job; the labour is extremely mobile—every gang, if not every individual, arriving by car. In order to accommodate the part-day gangs, the contractor may wait until several houses are ready, and in this case the working days are not immediately consecutive, and the duration of the schedule is extended by one or two days. A builder who is building considerably less than 250 houses a year may decide to leave longer gaps between the working days, thus allowing more latitude for the various trades. It is for these reasons that average figures of eight to twelve weeks are quoted in various surveys on the speed of housebuilding, in contrast to the minimum of six shown in Figure 50. On average, conventional builders take about 50% longer to complete their houses, but some of this longer period should be attributed to the fact that these builders tend to have a smaller annual output than the others.

146. The clockwork-like precision suggested by this schedule and description sounds utopian, but there are good reasons why it is practical, and in fact typical, in U.S. housebuilding. First, there is no shortage of materials, so that the builder is not likely to be held up by delays in delivery, even for those items which are not included in the house package. Secondly, sub-contractors are apparently more plentiful and more mobile, and in any case, the builder with an average annual production has considerable latitude in timing within his annual programme. The problem of timing increases with the volume of the builder, and it is of interest that one larger contractor visited, who was building one house per day throughout the year, had ceased employing sub-contractors and was adjusting the size of his own gangs so that each man had a full day's work. There was still the problem of different-sized houses, but the idea of getting through in a day was so ingrained that the men did in fact complete the work on time. Obviously the pace varied a little from day to day, but both employer and employees appeared to be satisfied with this arrangement. Thirdly, the delivery of the house package is a firm anchor to which the remainder of the schedule can be tied. The builder knows with certainty that at the end of a single day's work on the superstructure he will have a working space which will be unaffected by external weather conditions. This creates confidence that the schedule can be adhered to, and that there will be no changes either for the men or for the delivery of materials. Fourthly, the details of the standard method of construction, which have been developed over a long period, are now so well worked out and understood that the parts of the building fit together without trouble or delay, and under these circumstances it is easy to be productive. Moreover, these details have been worked out in such a way that each trade can carry out its own work without assistance from others—the electrical fittings shown in Figures 28 and 29 are an example of this. Finally, this productivity is further increased by intense specialisation. For example, plasterers have now been largely superseded by dry wall lining firms, who employ hangers and spacklers, i.e. one group which fixes the plasterboard and another which tapes and fills the joints. Within these two groups there may be further specialisation; one man may cut, fit and hang the board, by nailing round the perimeter, while a second does the intermediate nailing; ceiling spackling and wall spackling may be done by different men. The gang erecting the shell of the house are drawn from a different group from those working internally, and the man who installs the door units is unlikely to fix the skirting.

147. *Plasterboard dry walling*. As shown in Figure 51, each man works independently, using tapered edge plasterboard, marking out the sheets required with a steel tape and tee square, and cutting them to size. When sheets are to be placed on the upper part of the wall or ceiling, several nails will be positioned in the plasterboard sheet before lifting it from the horizontal stack. It is then possible for one man alone to lift the sheet into position and to secure it in place; only when very large sheets are used on the ceiling will two men work together. In some cases the plasterboard is carried over the windows, and the opening cut out later. The next operation is the filling and taping of the plasterboard joints and the spotting-out of the nail heads (Figure 52). Four men will complete this operation in two hours—two, on stilts, working on the ceiling joints and two on the walls. Subsequently, the joints will be feathered out in two successive coats to a width of 9″ or 10″. Although a total of only 35–40 man hours are required for the whole of the dry walling, no less than four working days are allowed for the finishing processes. Great emphasis is put on the need for control of both temperature and humidity. A moisture content of 9–14% for the timber is recommended, and in winter heating is provided to give a temperature of 55–70°F. If the timber has a high moisture content when the plasterboard is fixed, shrinkage, due to drying out when the building is complete, will result in loosening of the contact between plasterboard and timber, and will cause nail-popping, i.e. the protrusion of nailheads above the surface of the board. A constant temperature of 55°F. is recommended throughout the fixing and jointing of the plasterboard and until the house is occupied, in order to ensure even drying out of the board and joints. A one-day process has been developed, but this utilises a two-part filler with a limited pot life and few builders have yet adopted it. To obviate the spotting-out of nail heads, their appearance is sometimes disguised by giving a textured finish to the wall; this is obtained by smearing the jointing compound over the wall surface so that it adheres to part of the surface only.

148. *Services*. As already described in this section, work on heating ducts, and on water and gas supply pipes below the ground floor, will have been completed before the commencement of the superstructure. Once the shell of the house is complete, possibly even before many partition frames are in position, the bath will be installed; at this stage there is still comfortable working space in the service areas (Figure 53).

149. *Internal decoration*. Painting is usually carried out with brush or roller, depending on local union rules. On two sites visited, however, spray painting was used, and here one man could complete one house in three hours. The success of this operation lay in the well thought out masking details. The floors were covered with thick building paper as soon as they were laid. This is simple with platform construction as the whole floor or sub-floor is unobstructed at the erection stage, and the paper can be secured under the external wall panels. In setting the aluminium window units into the wall panels, the builder used for flashing a whole sheet of polythene rather larger than the unit, and this covered the inside face of the window and frame: reference to Figure 32 will clarify this. The third measure was to leave the pre-finished internal doors in their polythene covers. The painter could then spray all wall and ceiling surfaces, including wood skirtings and architraves. The only remaining

51 site operations: fixing plasterboard (top left)

Builder: Levitt and Sons Inc., Levittown, N.J.

The arrangement of nails in pairs helps to eliminate nail-popping.

52 site operations: filling and taping plasterboard joints (top right)

Builder: Gateway Corporation, Indianapolis, Ind.

Note the use of metal beading on all external corners. See also Figure 23.

53 site operations: services within the building (bottom left)

Builder: Pauly and Company, Cincinnati, Ohio.

The upstanding lip of the bath as shown in Figure 27 can just be seen. Switch boxes and socket outlets have been fixed directly to studs.

54 site programming schedule (opposite)

Builder: Fox and Jacobs, Dallas, Texas.

The numbers in the squares are the house serial numbers. As each operation is completed, its square is hatched in. The effect of failing to complete an operation is shown in operation 5. Shingling the roof will not affect other operations and a straight line gap will appear until the work catches up. The more serious effect of failing to complete an operation inside the house is shown in operation 9 as an ever-widening gap shows up on successive days.

OPERATION

	DATE	5-10-64	6-10-64	7-10-64	8-10-64	9-10-64						
	WORK DAY	182	183	184	185	186						
1	LAYOUT FLOOR SYSTEM	9067	9068	1248	1249	1250						
2	FRAME	9066	9067	9068	1248	1249						
3	ROOF FRAME TOP OUT	1247	9066	9067	9068	1248						
4	CORNICE I.S. FRAME DECK DUCT	1246	1247	9066	9067	9068						
5	SHINGLE	1245	1246	1247	9066	9067						
6	ROUGH ELECTRIC	1244	1245	1246	1247	9066						
7	O.S. PAINT ELEC. INSP. INSULATE	1243	1244	1245	1246	1247						
8	2nd. INSPECTION	1242	1243	1244	1245	1246						
9	SHEET ROCK - BRICK	1241	1242	1243	1244	1245						
10	TAPE - BRICK	1240	1241	1242	1243	1244						
11	1st. BED - CLEAN BRICK	1239	1240	1241	1242	1243						
12	2nd. BED - CUT FLATWORK	1238	1239	1240	1241	1242						
13	TEXTURE - SET & GRADE FLAT	1237	1238	1239	1240	1241						
14	TRIM CER. TILE POUR FLAT MET. TILE	1236	1237	1238	1239	1240						
15	FLATWALL - BACKFILL	1235	1236	1237	1238	1239						
16	CABINETS SAND FLOORS	1234	1235	1236	1237	1238						
17	FLOOR TILE 2nd. O.S. PAINT	1233	1234	1235	1236	1237						
18	ENAMEL WALLPAPER	1232	1233	1234	1235	1236						
19	HARDWARE - BLINDS MARBLE - CLEAN WIND.	–	1232	1233	1234	1235						
20	PLUMBING & ELECTRICAL TRIM	1231	–	1232	1233	1234						
21	TOUCH UP PLUM. & ELECT. FINAL	1230	1231	–	1232	1233						
22	FINAL INSPECTION	9065	1230	1231	–	1232						
23	CARPET SET METERS	9064	9065	1230	1231	–						
24	FLOR. CON. F & J RELEASE	9063	9064	9065	1230	1231						

operations were the fixing of electrical cover plates and door handles. Painting of the relatively small areas of kitchen and bathroom was by brush.

Site programming

150. One builder visited consolidates his individual house schedules into a composite schedule, which enables him to see at a glance the progress of the job (Figure 54). The operations are listed vertically in their daily groups, as in the single house schedules, but no dates are attached to the days; horizontally, a space is allocated to each working day. The serial numbers of the houses are written in on the squares of the chart, in such a way that the daily progression in each house is maintained, i.e. the serial number for each house repeats diagonally down and across the chart. Ideally, it should be possible, at the end of each day, to cross off a complete vertical column. Any deviation from this immediately shows up the effect on succeeding houses.

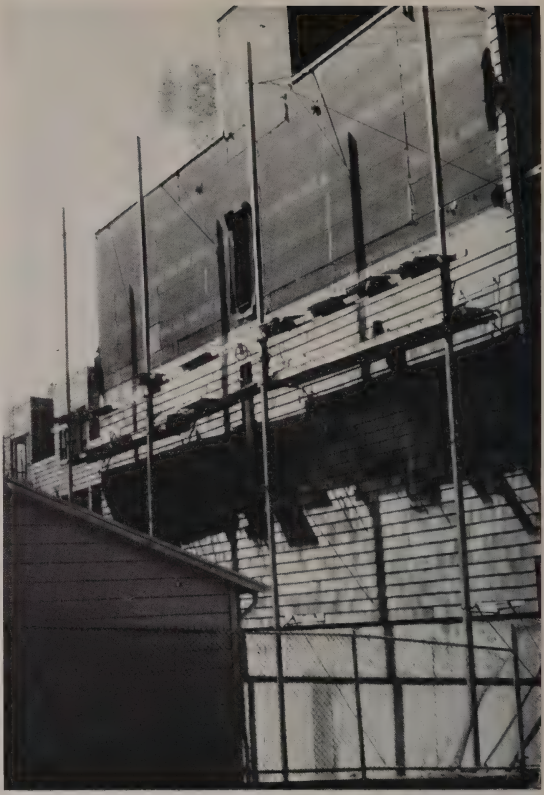
151. Critical path methods for programming building operations are not generally used by homebuilders; the six-week cycle produced by the existing methods of work scheduling is, for many builders, adequate. Some builders constructing complex schemes of flats are experimenting with C.P.M., and some home manufacturers use the method as a research and development tool in the design of their house types.

152. Operational studies have been carried out by the National Association of Home Builders and others with the object of helping the builder to reduce costs. These studies utilise time-lapse films in which a camera mounted in a fixed position takes a single frame at set intervals. The film is then run through a cine projector and a speeded-up version of the site operation is seen; for example, a frame taken every 12 seconds will produce a 40-minute film showing a whole day's work. The film illustrates clearly the pattern of movement on the site, and can be run at a slower speed for the analysis of apparently unnecessary or difficult operations.

153. The National Association of Home Builders study—TAMAP (time and methods analysis programme)—also included work studies and an analysis of the materials used. Among many useful and detailed recommendations, it pointed out: that savings in materials, through the elimination of waste at the design stage, tend to give easier savings than those obtained by reduction in labour items, as materials are now more than twice labour costs in total; that double handling adds nothing to the value of a house; that shop fabrication of complicated assemblies is cheaper and more satisfactory than site assembly; that as carpenters and others tend to nail claddings, sheathing and lining materials to every stud, the inclusion of unnecessary studs involves not only the cost of the material but also that of fasteners and labour; and that the pre-packing or bundling of groups of small related components can save considerable time on site. Above all, the study sought to convince the builder of the value of developing a questioning attitude to all the design aspects of his houses, and of pre-planning all his site operations; typical check lists and a pro forma critical examination sheet were produced for this purpose.

Equipment

154. *Tools and mechanical equipment*. Mechanical trench diggers and telescopic boom cranes have already been mentioned. Smooth finishes to concrete slabs are obtained by a manually operated float; no power floats were seen. All carpentry work was manually nailed, even to concrete—masonry nails were used for this. Contractors who cut frame members on site usually have electrically operated hand-held saws. Electrically-operated drills and screwdrivers were used for joinery fixing. One contractor used loose fill insulation and this was blown into place mechanically through a hose from the supply lorry.



55 scaffolding

The platform can be adjusted so that the work is always at a comfortable height, and the minimal obstruction allows general inspection of the work as it proceeds.

155. *Scaffolding*. Very little scaffolding is used, and when it is, it is light and portable. In two-storey buildings, upper storey wall panels and roof trusses were manhandled up a framed plywood ramp set at an angle of 30°. An inclined conveyor belt was used for hoisting asphalt shingles. For the fixing of shingles or boards as cladding, the scaffolds consisted of two vertical timber posts fixed into the ground and attached by straps to the face of the building, with adjustable metal cantilever brackets supporting a horizontal plank (Figure 55). Short step ladders were used to reach the top of wall panels (Figure 51), and plasterers fixing ceiling board were seen using stilts (Figure 52). External painters used cradles hung via offset brackets from the roof.

Cost and manhours

156. Although a great deal of information is available on the cost of housebuilding in the United States, to make it meaningful in this country by relating it accurately to British costs would require a detailed analysis beyond the scope of this study. The study would need to appraise not only actual quantifiable differences in housebuilding between the two countries, but also differences which have no monetary value in reality. In the first category would come such factors as differences in house types, average areas, standards of performance and equipment, methods of construction with their differing labour requirements, and costs of labour and materials.

157. In the second category, a valuation would be required of such factors as the effect of the different proportions in the two countries of building for private individuals and public authorities; and of differences in site wage rates, and their consequential effect on builders' site organisation, and on the attractiveness of the work to the operatives. The information in this section on cost and manhours is given solely because of its intrinsic interest.

Cost

158. The U.S. Department of Labor has published a survey* of the labour and materials requirements for houses. The survey is based on a representative sample, by geographic region, state and locality, of 101 houses, built mainly in 1962. The sample ratio is 1 in 7,400, but the effective sample is larger as some of the individual reports represent many similar houses within large housing developments. The typical U.S. house described in paragraph 39 predominates in the survey. 87 of the houses were built in frame construction, as described in this study, and used prefabricated elements to a varying extent; 10 of these houses were constructed from manufactured packages. The other 14 houses in the survey were of brick or concrete block construction. However, the houses in the survey are 13% larger, on average, than those described in paragraph 39, and the overall prices consequently higher, as follows:

area (to outside faces of external walls but excluding garage)	1,240 sq. ft.
construction price (including construction profit)	£5,210
market value (selling price inclusive of land)	£6,325

159. As the sample contains many variants which affect unit cost, no useful cost per square foot can be derived from these overall figures. The average cost per square foot of 77/– given for the 38 houses in the survey which had garages but no basements most nearly corresponds to the figures which would be obtained by British methods of calculation (see footnote to paragraph 39). Cost information obtained directly from manufacturers and builders gave a rather lower average of 65/–, probably because the firms visited were drawn from the largest and the most efficient.

160. The construction prices quoted above consist of the construction cost plus the builder's overhead and profit, and his financing and sales costs. The following cost analyses of four typical frame construction houses were obtained from home manufacturers and builders, and are based on construction cost only; this is usually 25–30% less than the construction price. All four houses were built from single-storey packages supplied by home manufacturers.

161. Analyses B and D allow for typical minimum footings only. The packages contained sheathed wall panels with pre-glazed windows, roof trusses, roof sheathing and shingles, partition frames, external and internal door units, kitchen cabinets and

house	A	B	C	D
area of house sq. ft.	854	1,152	908	901
garage	256			
carport		216		
basement	854			
basement	£773			
slab		£191	£277	£123
package supply	1,164	1,394	910	1,126
erection	179	145	112	105
roofing shingles				
labour	20	14	20	9
cladding				
brick materials	100	193	290	
labour	136	161		
wood siding materials				135
labour				
plumbing materials	295	(190)	196	(128)
labour		106		86
electrics	74	88	63	86
heating materials	134	(80)	(60)	(46)
labour		24	54	9
plasterboard materials	140	97	33	72
labour		74	48	61
external painting	37	37	90	26
internal painting	66	78		64
flooring	140	75	60	62
wall tiling		61		17
TOTAL	£3,258	£3,008	£2,181	£2,065
walks, drives and steps	15	53	18	21
site works		45	30	12
landscape	43	32	20	32
CONSTRUCTION COST	£3,316	£3,138	£2,249	£2,130

sink. In house A, the package also included the suspended ground floor; in houses B and D the plumbing materials; and in houses B, C and D the heating materials (price shown in brackets in each case) were supplied with the package, and the price should be added to the package supply to give its total price. In house C, plasterboard was fixed to all wall panels in the factory; the

* Bulletin No. 1404 of U.S. Department of Labor, Washington, D.C., *Labor and materials requirements for private one-family house construction.*

£33 is for the ceiling board only. The price of the house package supplied by the home manufacturer usually varies from 25–33% of the construction price, though this proportion rises to 66–80% for manufacturers who supply all materials, and carry out plumbing, wiring and the lining of wall panels in the factory. The labour content of the house package varies between 10–25% of its price.

162. In the U.S. Department of Labor survey the average distribution of wages, materials and other costs is given as follows: on-site direct wages 22%; materials, supplies and equipment 48%; administrative off-site salaries, central office and yard operation expenses, sales expenses, insurance and taxes, plus other overhead and profit 30%. For the package houses the distribution is: on-site direct wages 18·5%; materials, etc., 51·9%; and administrative off-site salaries, etc., 29·6%. No comparable figures are available for either the private or the public sectors of British housebuilding, and though a general average figure of 60% materials and 40% labour is often quoted, its basis and content are not ascertainable.

Manhours

163. The U.S. Department of Labor survey gives the following figures on labour requirements:

	number of houses	on-site manhours per $1,000 of construction price	average area of houses in square feet	total manhours per house
All houses	101	72·1	1,240	1,048
Package houses	10	55·1	1,155	793

164. The requirement of 1,048 manhours for a house of 1,240 sq. ft. compares favourably with the typical figure quoted for Britain of 1,300 to 1,800 manhours for houses of approximately 900 sq. ft. It would appear that the lower manhours for the United States are attributable to the rationalisation of the method of construction and of the work schedules, and to the use of pre-assembled units such as pre-hung doors and roof trusses. The still lower figure for the package houses shows the further reduction obtainable by the prefabrication of wall panels, and by the sorting out and orderly arrangement of components before delivery to the site.

165. The survey also gives information on the effect of different cladding materials on manhour requirements per $1,000 of construction price: brick or stone veneer 82·7; wood 70·9; asbestos shingles, aluminium sidings, etc., 67·8; and stucco 59·9 manhours. In the survey there is an analysis of the distribution of trades within the overall manhour requirements, and from this the following information has been prepared:

	All houses		Package houses	
average area of house	1,240 sq. ft.		1,155 sq. ft.	
	number of man-hours	per cent	number of man-hours	per cent
all occupations	1,048	100·0	793	100·0
supervisory, professional, technical and clerical	30	3·0	6	0·8
carpenters	363	34·6	250	31·6
painters	100	9·5	68	8·5
bricklayers	57	5·5	29	3·6
plumbers	55	5·2	68	8·5
cement finishers	41	3·9	62	7·8
electricians	29	2·8	35	4·4
plasterers	21	2·0	5	0·6
sheet metal workers	19	1·8	16	2·0
roofers	14	1·4	11	1·4
operating engineers	14	1·4	15	1·9
tile setters	10	1·0	9	1·1
softfloor layers	9	0·8	6	0·8
lathers			4	0·5
all other skilled workers*	35	3·3	23	2·9
labourers	156	14·8	129	16·4
helpers and tenders	88	8·5	54	6·8
truckdrivers and watchmen	4	0·5	3	0·4

* Includes terrazzo workers, plasterboard installers and finishers, insulators, glaziers and ironworkers.

166. Information obtained from four firms showed that manhours in the factory were approximately 200 and 400–600 when the cost of the package was 25% and 66–80% respectively of the total construction price.

167. Manhour figures for mobile homes are given in paragraph 180, for panelised houses in paragraph 192 and for sectionalised houses in paragraph 195.

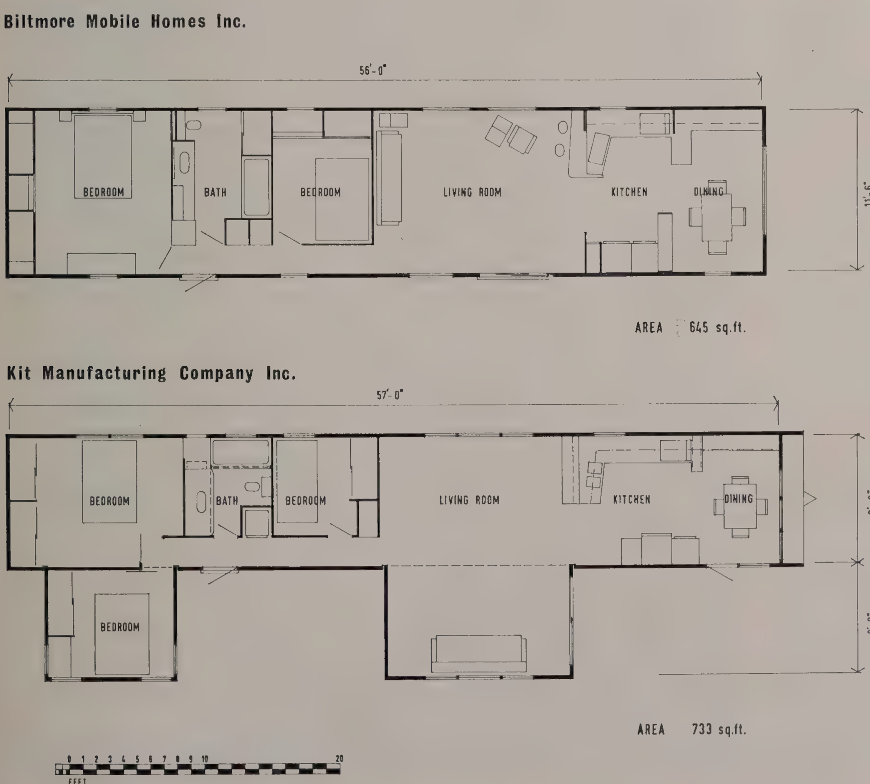
Mobile homes

Development and use

168. Mobile homes have their origins in the travel trailers or caravans designed for use by holidaymakers though they are now a rather different product. Travel trailers were first produced industrially in the early 1930s, and it is estimated that there are now 400,000 in use in the United States. They are highly mobile and are intended for short-term occupancy; nevertheless, they are well equipped, often with heating units, refrigerators, washroom facilities and sleeping accommodation for up to six people. In 1964 the average price was £640. The trailers can be made up to 8′ 0″ wide and 29′ 0″ long, regardless of weight; within a weight limit of 4,500 lbs. they can be of any length. They are towed by the owners, using standard motor cars, and can be parked in any of the 3,200 special trailer parks, and numerous other camping sites, to be found in every part of the United States.

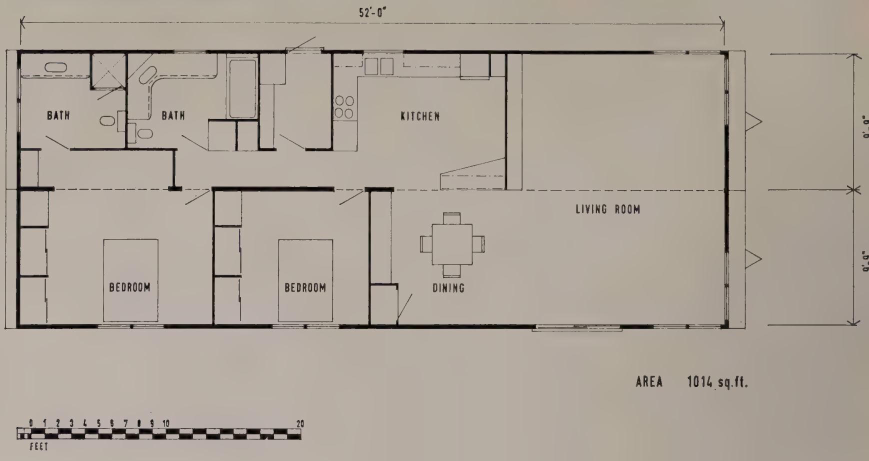
169. After the war returning ex-servicemen, and defence and building workers moving to new areas with their families, required temporary housing. Retired people found that the compactness of the trailer suited their needs. There was a shortage of conventional housing, so many people began living permanently in trailers. Manufacturers began to develop larger units; in 1954 the limit on width was increased to 10′ 0″, and in 1960 to 12′ 0″, and both increases permitted significant improvements in internal planning. Lengths were growing also so that units of 40′ 0″ to 60′ 0″ were common, and currently the maximum practical length is considered to be 75′ 0″. The maximum width and length give an overall area of 900 square feet. Some manufacturers make larger units by supplying additional rooms in the form of boxes which travel within the main body of the mobile home, and which, on site, are pushed out through a corresponding opening in the long wall of the unit.

170. Alternatively, two units are placed together giving homes from 700 to 1,500 square feet in area (Figure 56). Equipment has improved too, so that heating and air-conditioning, baths and showers, washing machines and refrigerators, and well-equipped kitchens are provided. In fact, while the homes may be more compactly planned, the amenities are of the same standard as those in conventional homes. In addition, mobile homes are sold fully furnished with beds, built-in cupboards, tables, chairs, rugs, light fittings and curtains, so that the only items that the owners have to provide in addition are crockery, cutlery and linen (Figures 57 and 58).



56 mobile homes — typical plans

Kit Manufacturing Company Inc.



56 (continued) mobile homes—typical plans

171. Mobile homes range in price from £1,100 to £6,400, the total average price, and price per square foot being £2,000 and 70/– respectively. 20–25% of them are bought for cash and the rest are financed with a loan, usually for seven years at 6% with a down payment of 25–33%. The repayment on the average £2,000 home would be £25 a month. Mobile homes are bought in the same way as motor cars, through dealers, and used homes can be traded in for new models.

172. Dealers will renovate old models and resell them, perhaps as permanent homes or possibly as vacation or weekend homes.

173. Mobile homes are towed to the site by commercial transport companies, and of the million homes currently in use as primary dwellings, over 87% are located in mobile home parks (Figure 59). There are over 20,000 parks in the United States, the largest containing 1,200 homes: the average number is 55. In the parks each home stands on a concrete or gravel base, and is connected by flexible tubes to adjacent mains services and drainage points. The homes remain on their wheels and are additionally supported by jacks, and a skirt is sometimes placed round the base of the home to seal off this space. Most parks have a space alongside each mobile home for the owner's car, and in some cases a permanent carport with store is provided. The older parks were planned at a density of 18–20 homes per acre, but with the increasing size of the homes and the trend towards spaciousness, densities of 10–12 are now common. Some of the parks have shops, meeting halls, restaurants, swimming pools, putting greens and other sports facilities. The rent of a space in a mobile home park costs from £7 to £20 per month; in some Californian parks it is now possible to buy sites freehold.

174. Mobile homeowners do not pay local taxes, only a small annual licence fee, and this has been the cause of dissatisfaction with mobile home parks among neighbouring conventional home-owners. The Mobile Home Manufacturers Association and the Trailer Coach Association maintain, and have established in the courts, that, per acre, a mobile home park produces more revenue than a conventional suburban development; moreover, there are fewer children in mobile homes, thus requiring less local educational expenditure, and the parks maintain their own roads.

57 mobile homes — internal view

Manufacturer: Divco Wayne Corporation, Union City, Mich.

Living room with kitchen in the background. The space behind the kitchen fittings forms a utility room, and the corridor in the background on the left leads to bedrooms and bathroom.

58 mobile homes — internal view

Manufacturer: Divco Wayne Corporation, Union City, Mich.

The bathroom conforms to conventional American standards.

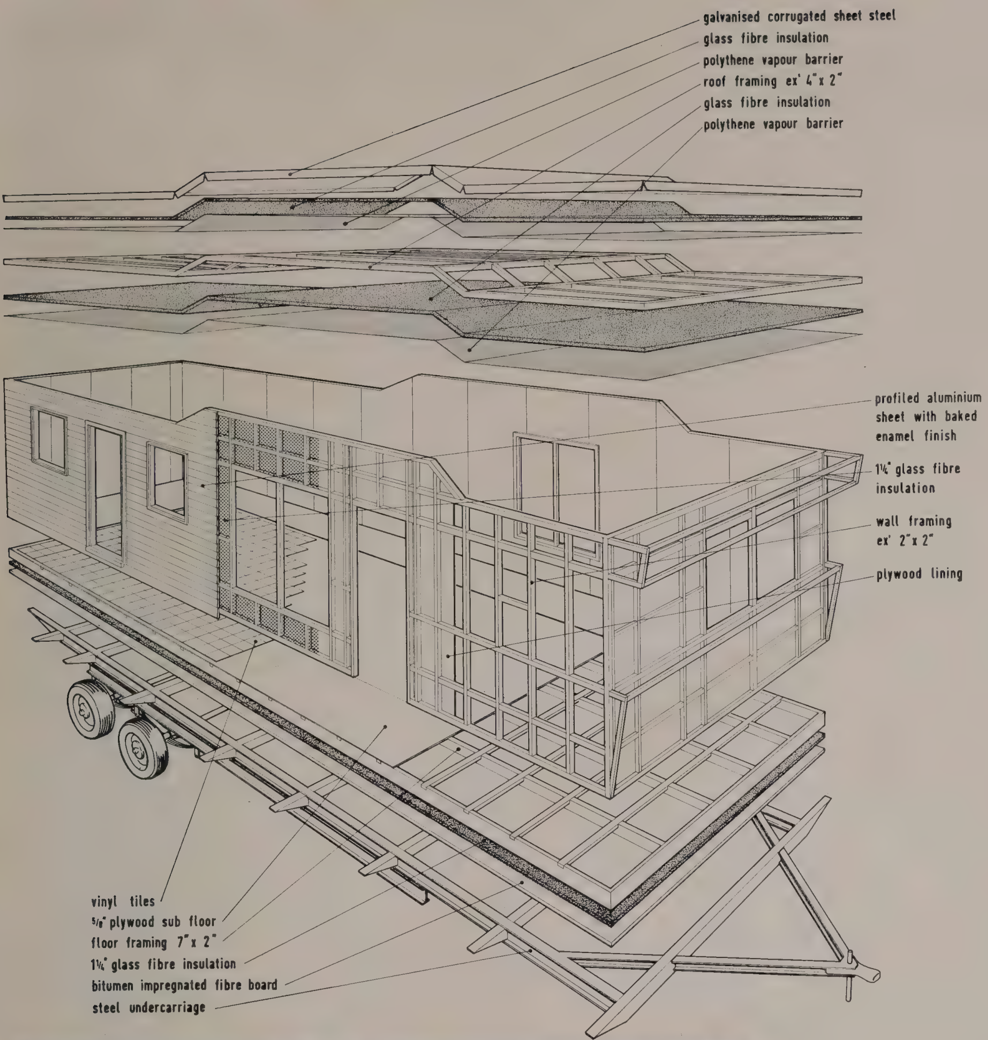
175. Once in position mobile homes are rarely moved: in fact, mobile home owners do not move more frequently than people of similar age, income and occupations in conventional homes. Thus, from being a temporary expedient, mobile homes have become many people's preference in housing. 4,000,000 people, more than 2% of the United States population, now live in mobile homes, most of them retired people, married couples, or families with young children. Most of the retired people have lived in conventional homes, but when their children grew up and moved away, and the husbands retired, they found it useful to be able to cut down on the expense, and on the time and energy required for running a large house. Some moved first to a flat but found it too restrictive after a house, or that it was not easy to make new friends. For these people a mobile home in a park with community facilities offers the following advantages: a compact, easily run and inexpensively maintained home, a small plot of land in which gardening is a hobby, not a burden, the companionship of similar people, and the participation with them in sports and other activities. A few retired people move south for the winter and back again to more northerly states for the summer.

176. For younger families, the otherwise played-down mobility of their homes is an advantage. The husband may be in the armed services or a construction worker in jobs which change location every two or three years. For some workers it is an advantage to be able to move from areas in which employment is dwindling without making a loss on the sale of a conventional home. For wives who go to work and for mothers with young children the convenience of mobile homes is an advantage, and some mothers are glad of the economy. Most of this economy seems to be in the running costs, for though the capital cost of a mobile home is less than that of a conventional home, the shorter financing period and the cost of renting a site appears to bring the monthly repayment up to that of the cheaper homes. The mobile home repayment includes all furniture and fittings, and for some the simplicity of one combined mortgage and hire purchase bill is an attraction. Mobile homes are paid for more quickly than conventional homes, but their value usually depreciates more quickly. However, the relative values of the two types of home are not as heavily weighted in favour of conventional homes as they would be in Britain where the land on which the conventional home is built has a scarcity value, where the supply rarely exceeds the demand, and where houses become obsolete more slowly.

Construction and fabrication

177. The construction of mobile homes is shown in principle in Figure 60. A floor framework with 6″ × 2″ or 7″ × 2″ joists running along the unit is mounted on a chassis of japanned steel channels. This has a double or triple wheel unit at a one-third point of the length and jack supports at the far end. Between the timber framework and the chassis is a layer of fibreboard to deaden vibration. Glass fibre thermal insulation is placed between the joists, and a sub-floor of plywood above. Floor finishes are of vinyl tiles or carpet. The wall framing is supported on the floor and is strapped to it. The frame members are ex 2″ × 2″—half the section used in conventional construction—spaced at 16″ centres. Horizontal cross members are let into the studs for stability and to support the cladding of stoved enamel aluminium sheet. Glass fibre insulation fills the wall cavity and the internal lining is of plywood with a variety of surface treatments. Windows have aluminium frames and opening lights are top-hung or made of louvres. The roof has a framework of 4″ × 2″ timbers with thermal insulation and a polythene vapour barrier. The roof covering is made from a continuous roll of corrugated galvanised sheet steel; this is turned down over the top of all wall edges so that there are no joints on the roof surface. Water service pipes, drainage and heating ducts are run in the floor, and electrical services in the walls and roof. Cupboards are framed conventionally but with lighter sections, as they do not have to be transported independently, and in addition they receive direct support from the structure.

178. The light frame members, which would not be permitted by building codes for conventional construction, are adequate because of the overall rigidity of the box structure with its



59 mobile home park (top left)

In this park near Seattle, Washington, a permanent carport with store attached is provided by the park management.

60 mobile homes: construction

Manufacturer: Divco Wayne Corporation, Union City, Mich.

61 mobile homes: fabrication

Manufacturer: Divco Wayne Corporation, Union City, Mich.

In the centre of the photograph, plywood internal linings are being fixed to the external wall framing, and the completed assembly will be lifted into position on the floor of the mobile home on the right of the picture.

frequently-occurring interior cross walls and cupboards. The resilience of the box's connection with the ground must also dampen the effect of wind pressure. The atmosphere in the United States is generally far less corrosive than in Britain, so that the galvanised roof could be expected to have a far longer life than here. In any case, long-term durability does not seem relevant to mobile homes, since the terms under which they are bought, financed and traded-in are more akin to those used for motor cars than for houses. The Mobile Homes Manufacturers Association and the Trailer Coach Association, finding that they are now producing almost 20% of the nation's housing without being subject to any building codes, have taken an extremely responsible attitude towards standards in the industry. For example, they have initiated the production of an American Standard (A119.1–1963) for the installation of plumbing, heat producing and electrical systems, and equipment, in mobile homes and travel trailers, to protect health and ensure safety.

179. The fabrication of a mobile home begins with the floor. The framework is made upside down on a work bench and the layer of fibreboard applied. The framework is then turned over on to the chassis or on to a system of dollies, and pushed on to the next station on the assembly line. Here the services, heating ducts and insulation are installed in the floor. At the next station the sub-floor, floor finishes and probably the bath are fixed. Next, the assembly line (Figure 61) passes between two work benches on which the longitudinal external wall frames and internal lining have been fabricated, and these are placed in position. Then the roof framework is fixed, and so on, the mobile home proceeding on down the assembly line and drawing materials, components and sub-assemblies from bays alongside each station. Finally the curtains are hung and the furniture moved in.

180. With this method of assembly, in which the house is completed in the factory, the work can be carried out under ideal conditions, and excellent standards of workmanship obtained with an efficient use of labour. One manufacturer, who buys in his cupboard units, builds his average 600 sq. ft. home in 80 manhours. Another, who makes his own cupboards and has a higher standard of equipment, builds 500 and 1,200 sq. ft. homes in 165 and 600 manhours respectively. Direct wages amount to approximately 10% of the retail price of a mobile home (excluding site costs) compared with 18–22% for conventional construction. Material costs are proportionately about the same, but the higher overhead for mobile homes—40% including dealers' expenses, compared with 30% for conventional construction, reflects the effect on overheads of different methods of marketing and re-sale facilities.

Future possibilities

181. Mobile home manufacturers envisage continuing expansion because of the increasing proportion of the United States population who come within the categories of young families and retired people. The industry associations are sponsoring at least two ideas which would have the effect of disguising the mobile home's long box shape. The first is to use two mobile homes in conjunction with conventional construction, the mobile homes set parallel to one another and forming bedrooms, kitchen and bathroom, with the intervening space roofed and glazed to form a large living area, the whole house being approximately square on plan. The second, at present being considered for travel trailers, is a circular ramped multi-storey garage with every trailer facing the circumference, and thus getting a view. The building is designed to be sited alongside a motel so that the dining and other facilities can be used jointly.

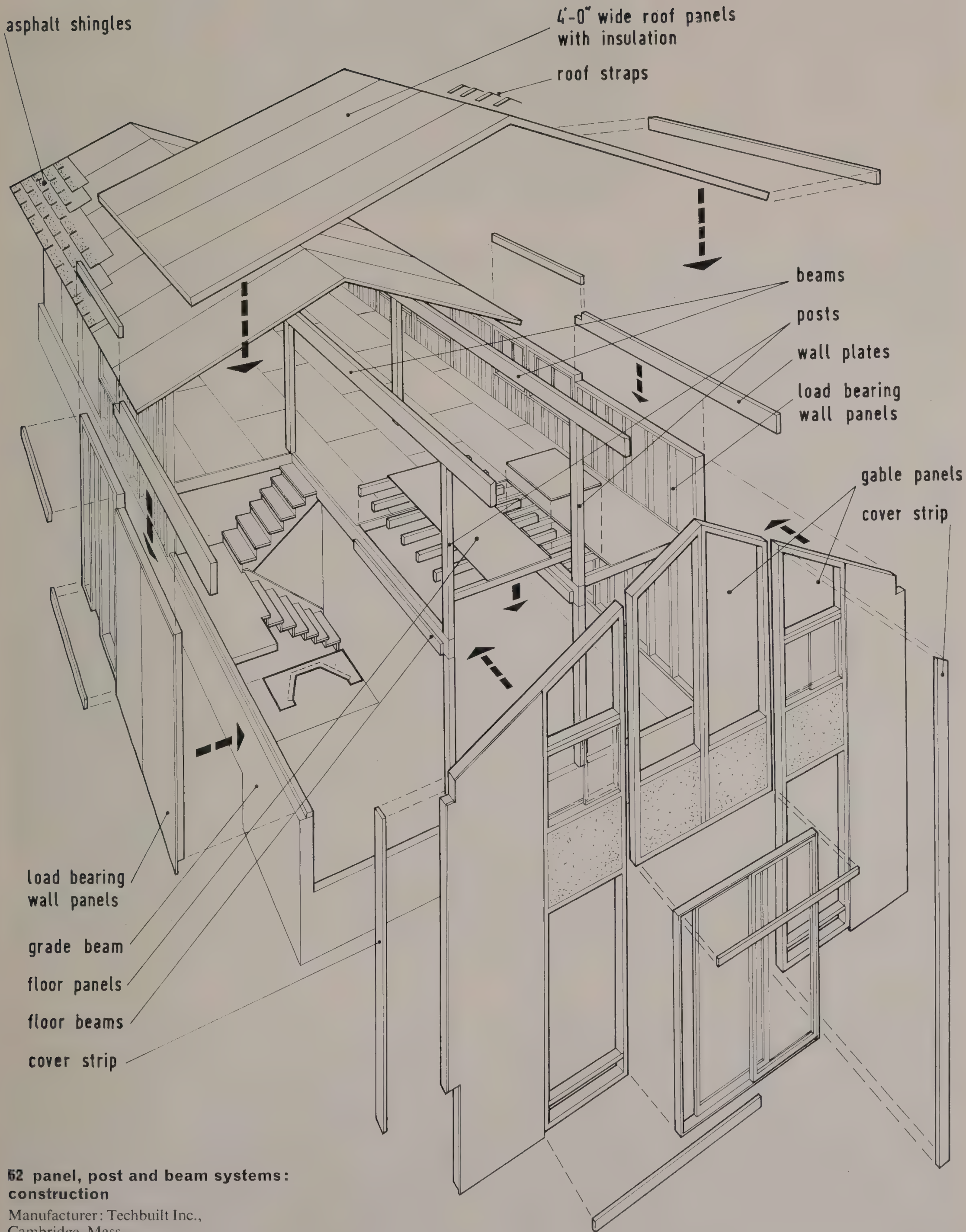
Other building techniques and developments

Timber panel, post and beam systems

182. Systems using a structural framework of timber posts and beams, with non-load-bearing infill panels, are rare in U.S. housing. All the systems of this general type which were seen used roof, floor or wall panels in conjunction with beams and posts.

183. Among the best known is Techbuilt Inc. (Figure 63), whose consulting architect is Mr. Carl Koch, A.I.A. The first house was built in 1953, and since then the firm has produced over 100 houses every year for a small and discriminating market, at a slightly higher than average price. There is a range of models but the firm also designs to order using the standard components. The designs are elegant and simple in conception and are executed structurally with a refreshing straightforwardness. The plans, which are rectangular or formed from a number of rectangles covered with a simple pitched roof, are based on a module of 4′ 0″, with widths of 24′ 0″ and 32′ 0″, and with partitions generally on the 4′ 0″ grid, though 1′ 0″ and 2′ 0″ positions are used occasionally. In section, the ceiling follows the slope of the roof, so that internally the designs have great spacial interest. In two-storey houses, the lower storey has a standard floor to ceiling height of 8′ 0″, and the upper storey floor to ceiling height varies from 6′ 0″ to 10′ 0″, so that maximum use is made of the internal volume.

184. The structural system is shown in Figure 62, and from this it will be seen that the roof panels are supported at the eaves on external wall panels, and intermediately on lines of laminated timber beams and 4″ × 4″ posts. Floor panels in two-storey construction are supported in a similar manner. The roof panels are unusual in that they are not framed on all four sides; this obviates the doubling up of joists at the junctions of panels and thus effects a considerable economy. The panels are made in 4′ 0″ widths and consist of joists and sheathing plywood. There is no joist along one longitudinal side so that when the panels are placed in position on the roof, the joists occur regularly at 16″ centres and the free edge of the plywood on one panel is nailed to the protruding joist of the adjacent panel. The panel is stiffened laterally by the fixing, in the factory, of a sheet of plywood to the underside of the joists at the eaves, where it forms a soffit to the external overhanging part of the roof. The external wall panels are of the conventional frame construction, 4′ 0″ and 8′ 0″ wide and 8′ 0″, 10′ 0″ and 14′ 0″ high (for one-storey, semi-basement and two-storey respectively); they are insulated and are supplied with grooved plywood cladding or with plywood sheathing for use with site-fixed cladding. There is also a range of gable panels. The house designs are so arranged that windows occupy the whole of a 4′ 0″ or 8′ 0″ wide panel, and in the case of two-storey panels occur in both upper and lower storeys. The windows are unusual in that the fixed lights are glazed directly into special rebated 6″ × 2″ timber members which form the window panel frame; opening lights consist of aluminium units which are inserted into the rebated sections. In locations where spandrel panels are not glazed, medium density overlay plywood replaces the glass. The limited range of external wall panels makes it possible for the manufacturer, Acorn Structures Inc., to manufacture for stock during the winter months.



62 panel, post and beam systems: construction

Manufacturer: Techbuilt Inc.,
Cambridge, Mass.

185. Internally, a clean appearance is obtained by limiting the timber trim to internal door architraves and skirtings; all other junctions of plasterboard with windows, beams, etc., are controlled with concealed metal trim similar to that shown in Figure 23.

186. In other post and beam systems the beams, inclined for the roof, run across the building at 8′ 0″ centres, and support roof and floor decks made of planks as described in paragraph 76. The advantage is that no separate ceiling is required and the planks give a pleasant appearance; on the other hand, voids are no longer available for electric cables and heating ducts, and the routing of these services has to be specially contrived.

187. In all post and beam systems, planning needs to be on a generous scale if the appearance of beams at apparently random positions in smaller rooms is to be avoided. It is significant that most of the plans using this type of system are 1,500–3,000 sq. ft. in area.

188. One of the most interesting systems seen was the panel and beam system developed by Home Building Contractors Inc. (Figure 64). The president of the firm, Mr. Neal Reyburn, is an architect by training, but, as would be the case in Britain, is unable to maintain his registration. The firm's policy has been to develop a high degree of prefabrication and to achieve a rapid turnover. In order to do this, the firm both manufactures and erects its houses. Currently, the site erection of the finished house is completed by six men in two days, on basements or crawl spaces built under separate contracts. The range of models is based on a 4′ 0″ module, with one span, 24′ 0″, and one roof pitch; multiples of 3′ 0″ and 4′ 0″ are maintained internally and the house plans are arranged to give a central spine wall. Many of the components are used in several models.

189. A standard heart unit, 9′ 0″ × 8′ 0″ on plan and weighing 2,800 lbs., is supplied with every house (Figure 65). The unit is constructed of 4″ × 2″ framing and V-grooved hardboard, spray-enamelled inside the bathroom and with a timber grain print elsewhere. It contains a bath with shower, basin, w.c., an 80,000 BThU gas warm air heater, a 30-gallon water heater, 9′ 0″ run of kitchen cabinets fitted with a sink, and the usual bathroom accessories such as medicine cupboard, towel rails, etc. The arrangement of the bathroom has been well thought out and all the fittings are integrated into the design. Quality and appearance are higher even than those of conventional site-assembled bathrooms, which in the U.S. are high indeed.

190. The components are placed in position by means of a simple derrick (Figure 65) which travels to the site on the component trailer; on site, it is attached to the traction and cab unit, and receives power from the engine. The first component to be placed in position is a combined box girder and heating duct unit, which runs longitudinally along the centre of the building and provides intermediate support for the plywood and joist stressed skin floor panels, 24′ 0″ × 4′ 0″, that span across the building. The internal and external wall panels are of conventional frame construction and are completely finished in the factory, i.e. all the panels are wired, lined and decorated, and in addition the external panels are clad, sheathed, glazed and insulated. The panels are made in lengths, up to 16′ 0″, in such a way that straight-run junctions usually occur at places where a partition meets the junction at right angles, i.e. it becomes a T-junction. Most junctions therefore occur at internal corners and are masked by a small springy metal cove. The cove is factory-fixed, and is approximately ½″ across. It is sufficiently small and unobtrusive to appear merely as the rounding-in of the corner, and not as a separate entity, and it has none of the visual objections which usually apply to cover strips. Occasionally, however, cover strips are necessary, and these are then made of 4½″ × ¼″ timber and line up with roof beams overhead.

63 panel, post and beam systems: external view

Manufacturer: Techbuilt Inc., Cambridge, Mass.

64 panel and beam systems: internal view

Manufacturer and builder: Home Building Contractors Inc., Sedelia, Missouri.

65 panel and beam systems: heart unit

Manufacturer and builder: Home Building Contractors Inc., Sedelia, Missouri.
The heart unit is being lowered into position over the crawl space.

66 panel and beam systems: roof structure

Manufacturer and builder: Home Building Contractors Inc., Sedelia, Missouri.
An inverted T-beam is being fixed. The photograph also shows the pre-finished wall panels and the unobtrusive beam junction.

191. The roof structure (Figure 66) is supported on the longitudinal external walls and on the central spine wall; in some models a beam is required over the living room, and this occurs under the ridge of the roof. The roof consists of inverted T-beams at 4′ 0″ centres spanning across the building from the external wall to the central wall or beam, and of internally finished stressed skin infill panels. The horizontal arms of the T-beams are 4″ deep and line up with similar members at the tops of walls, thus forming a complete frame for the infill panels. Internally, therefore, the sloping roof has a panelised appearance, while the walls, except for kitchen and bathroom, are generally continuous; this gives an extremely pleasant appearance. Externally, in accordance with the dictates of the U.S. market, the panels are not expressed. The erection teams are sufficiently experienced generally to avoid damage to the panels. Polythene covers are available in the event of rain, but occasionally a room has to be redecorated internally. Any gouging or structural damage to the plasterboard is repaired by the firm, but it is part of the contract that the buyer shall clean off any spots or smudges, if necessary touching up from the small cans of paint supplied for the purpose. The buyer is also responsible for arranging for the services to be connected.

192. With this system, the total manhours per house (excluding the basement and service connections) are reduced to 500–600, of which only 100 are on site. Two-thirds of the construction cost is incurred in the factory, and the remainder is spent on foundations including service connections, transport, equipment, site wages and advertising and sales expenses.

Sectionalised houses

193. These are a further development of conventional timber panel construction. Three-dimensional units, two of which form the house, are produced in the factory, using assembly line techniques similar to those of the mobile home manufacturers. The two parts of the house travel at the same time along parallel assembly lines (Figure 67). The development has been aided by the Small Homes Council of the University of Illinois, whose research group produced a report summing up past experience, analysing the circumstances in which the use of the method is advantageous, examining the problems involved, and giving a range of suitable house plans. The house units are produced in widths up to 12′ 0″, the maximum generally permitted on the highway, and are hauled to the site on specially designed trailers. There they are placed in position on permanent bases by means of a crane or rollers. There is considerable experience of this type of operation in the United States, as many conventional houses are moved to make way for highway or other developments.

194. The materials and components used in the construction of sectionalised houses are identical to those used in conventional frame construction, though some additional stiffness is required for transport. Plywood is used for sheathing, in preference to less rigid materials, and extra members are inserted in the floor. The wall along the junction of the two production units has two sets of framing, one in each unit, and has to be sheathed, on the sides of the framing not covered by the plasterboard lining.

195. These additional materials costs, and those of the special equipment used for transport and on site, have to be paid for by a corresponding reduction in labour costs. This appears to be feasible wherever factory labour rates are rather lower than site rates, as is the case generally in the United States. Manhour

67 sectionalised houses: fabrication

Manufacturer: Continental Homes Inc., Boones Mill, Virginia.

The floor framework for a half house is mounted on rollers and will be pushed on to the next stations for the insertion of plumbing and the fixing of wall and roof assemblies.

68 sectionalised houses: erection

Manufacturer and builder: Northwest Homes Inc., Chehalis, Washington.

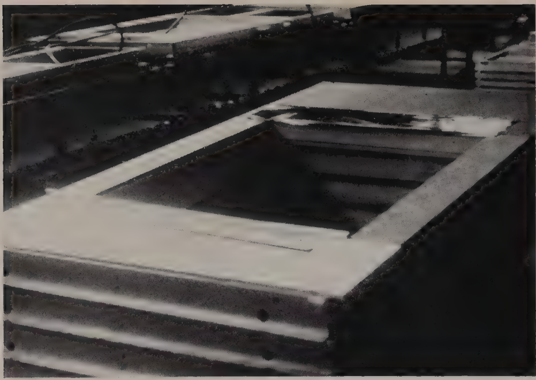
This is an experimental two-storey block of flats.

requirements are low; typical figures for houses of 1,000–1,100 sq. ft. are 550 manhours in the factory and 30 on site, excluding foundations and service connections. One firm aims to keep the on-site costs down to 10% of the total.

196. The method can be extended to larger houses, which would be made in three or more units. It is already being used for two-storey flats and motels (Figure 68). Each flat consists of two units 12′ 0″ × 30′ 0″, giving a total area of 720 sq. ft., and each unit is a complete box with joisted floors and ceilings. The top of the ground floor units and the bottom of the first floor units are lined with ½″ insulating board, and this ensures that the load from the upper unit is distributed evenly on the lower, and contributes to sound insulation between the units. The units are clamped together horizontally and bolted both horizontally and vertically. Between each pair of flats a 12″ gap is left for the plumbing stacks, which are constructed on site and are connected to the horizontal runs of plumbing already installed in the units. Access to the upper floor units is by a site-assembled external staircase and balcony.

197. The motel units are 10′ 0″ × 24′ 0″ and contain a bedroom and bathroom. Units are placed side by side and back to back, a gap being left along the centre of the building for the vertical service runs. Balconies are assembled on site, and in one project seen the building was being encased in brick veneer. In another scheme, it is proposed to use the box method for a four-storey motel building; here some, if not all, of the load will be transferred to ground through steel stanchions placed in the gaps between units.

198. The boxes weigh between 3 and 4½ tons and are lifted into position with a 10-ton crane.



69 systems using steel: external wall panels
Manufacturer: U.S. Steel Homes, New Albany, Ohio.

70 systems using steel: external view
Manufacturer: Armco Steel Corporation, Middletown, Ohio.

Systems using steel

199. Steel producers, whose material is not widely used in timber housing, are attracted to the market because of its enormous volume, and there have been many attempts to enter the field. To be competitive with standard timber construction, two main problems have to be solved; first, the steel, which is a more expensive material than timber, has to be used more efficiently to overcome the price differential; and secondly, the components have to be made so that the homebuilder's site labour, with its strong tradition of carpentry, can assemble them without loss of efficiency. The Lustron house, contemporary with and in many ways reminiscent of Britain's post-war prefabricated bungalows, affords a classic illustration of the attitudes and problems of this period. The house was made, whether the material was the most appropriate or not, almost entirely of steel, pressed porcelain enamel sheets being used for all internal and external surfaces. It was thought that the house would be economically viable if it could be produced in sufficient volume. Adequate capital, supplied by the Federal Government, was available to get production going, but as soon as the sale of houses started, opposition from opponents of federal subsidies for housing, and from other producers and manufacturers, etc., began to mount and eventually engulfed the enterprise. (If the money had been raised privately, similar opposition would probably have come from shareholders, because of the extremely long period required to build up to a break-even volume.) Finally, assembly techniques were utilised which were quite foreign to the site labour.

200. After several attempts to use steel in a radical manner, United States Steel has adopted a policy which takes standard timber construction as the starting point and develops alternative steel components to replace the timber ones and, where possible, to improve on their performance. The work is not, therefore, spectacular, though many interesting experiments have been carried out in a highly professional manner, and two useful products put on the market. The first is an internal wall panel, 4″ thick, 8′ 0″ high, and in widths of 4″ increments from 8″ to 4′ 0″; the framework consists of vertical light gauge steel studs and timber top and bottom rails, and the skins are $\frac{1}{2}$″ plasterboard. Detailed work has been carried out to ensure an adequate bond between steel and plasterboard and to develop an efficient assembly line manufacturing technique. The panel has two main advantages over similar timber ones, and over site-constructed partitions; there is no fixing from the outer surface of the plasterboard, so that pre-finished boards, such as those with vinyl coverings, can be used without cover strips or other nail-masking devices; secondly, with ordinary boards, all taping, jointing and nail-spotting is eliminated.

201. The second product is an external wall panel (Figure 69). This has a plasterboard lining as for the internal panel, and uses bitumen impregnated fibreboard as sheathing. The sheathing is fastened to the steel studs by barbs pressed out of the stud material; the ends of the barbs are turned over to secure the sheathing by placing the panel in a press. In panels containing windows it has been found possible to eliminate lintels by replacing the fibreboard sheathing over the window with plywood. The firm has also developed a steel siding which is cheaper than aluminium, and steel hangers for the vertical tension members of roof trusses. Development work is now proceeding on roof coverings and foundations (paragraph 78, item (*e*)). The 4′ 0″ and 2′ 0″ wide internal and external panels are standard products which U.S. Steel Homes, a subsidiary of U.S. Steel, manufactures on a continuous basis, the stock being used on receipt of orders from builders.

202. Two other steel firms were visited both with houses at the pilot development stage. The Armco Steel Corporation, which has thirty years' experience in prefabricated buildings for commercial and industrial use, is developing a house construction using corrugated sheet steel panels for walls, roof, ceiling and floor. The external wall panels are load-bearing and there are intermediate lines of steel purlins and columns (Figure 70). The other firm, the Rohr Corporation, whose main business is aircraft, has developed a wall system which uses a steel framework with foamed polystyrene sandwich infill panels. 2″ square steel columns at 4′ 0″ centres are fixed between continuous steel runners at top and bottom. The columns are load-bearing and act as splines to locate the infill panels. These panels are clad externally with asbestos cement and internally with vinyl-faced plasterboard.

The use of plastics

203. Although the successful development of load-bearing plastics for use in structural elements is still awaited, plastics are already used in many forms in U.S. housing. In 1962, 25% of the total output of plastics in the United States was used in the building industry, though this represented only 0·66% of total construction expenditure. The major use of plastics is in vinyl flooring, which has the advantage of being more resilient than the thermoplastic tiles commonly used in local authority housing in Britain. Other frequently used plastics are alkyd resins in paints, phenolic resins as adhesives in plywood, polythene as vapour barriers, pipes and wire coatings, and polystyrene as insulation and panel cores. The use of plastic coatings and films for wall and roof coverings has already been discussed (paragraph 88).

204. In most of these uses, plastics replace another material, and are used in the same way. On the other hand, foamed polystyrene and polyurethane used as cores for sandwich panels have produced significant changes both in the panels themselves and in other elements. First, there is the advantage of the very high thermal insulation value and its effect on heating systems.

Next, their extreme lightness and dimensional stability make possible the production of very large panels—one firm has been producing panels, complete with windows and doors up to 26′ 0″ in length—and this must affect the development of jointing techniques and the use of mechanical equipment on site. Finally, because of the excellent bond obtainable, the full strength of the skins can be developed and economies made in the materials. A number of firms are producing, or have produced, foamed plastic sandwich panels but they are not yet widely used. There are problems in the installation of electric cables in the panels, though special cables sheathed in high efficiency insulators, and thus of smaller diameter and more flexible than normal, have been developed. In some areas, the use of these panels is not yet approved in the building codes.

Automation

205. The most highly developed factory visited was that of Alside Homes Inc. The firm has a range of 12 model houses, ranging in area from 1,100 to 3,800 sq. ft., and in estimated construction price from £3,500 to £17,500. The average construction price is intended to be approximately £8,000, i.e. some 50% higher than the average discussed in paragraphs 158–162. Alside Homes has developed a system of construction (Figures 71 and 72) based dimensionally on 12′ 0″ × 14′ 0″ bays, separated by 4″-wide tracks. The tracks accommodate a load-bearing framework of 4″ × 4″ posts and 8″ × 4″ beams, both of rectangular hollow steel sections. The roof and floor infill panels are 12′ 0″ × 3′ 6″ × 5″ deep and are of stressed skin construction with wood framing, plywood skins and foamed-in-place polystyrene insulation. The roof finish is four-layer built-up bituminous felt with chippings. The ceilings below the panels are acoustic tiles on firring pieces and the floor finish is vinyl tile. These finishes are site-applied but the wall panels are factory finished. The external wall panels are foamed plastic sandwich panels, 8′ 0″ high, in six lengths up to 14′ 0″, and 4″ wide; the skins are aluminium with a stoved enamel finish and the core is foamed polystyrene. The window units are 8′ 0″ high and 3′ 0″ or 6′ 0″ long, aluminium-framed with double glazing and screens. There are no opening lights other than full-height sliding doors as all the houses are fully air-conditioned. Entrance doors are aluminium-faced with honeycomb cores. Internal divisions are mainly wood-framed cupboard units, but there are some wood-framed partitions; internal doors are full-height. Junctions between wall panels and posts are sealed with aluminium T-sections, fitted with vinyl sealing strips. The heating system is gas-warm air with ducts below the floor leading to floor outlets. The wall panels can be wired in the factory and all electrical accessories and fittings are supplied with the package. The kitchen and bathroom equipment and fittings are comprehensive and lavish.

206. The factory in which the components are produced is purpose-built and extensively equipped with automatic machinery. Orders from builder-dealers are fed into computers which transfer instructions directly to the control mechanisms of the machines on the production lines. There are production lines for steel columns and beams, wall panels, and floor and roof panels. Window, door and cupboard units are assembled in the factory.

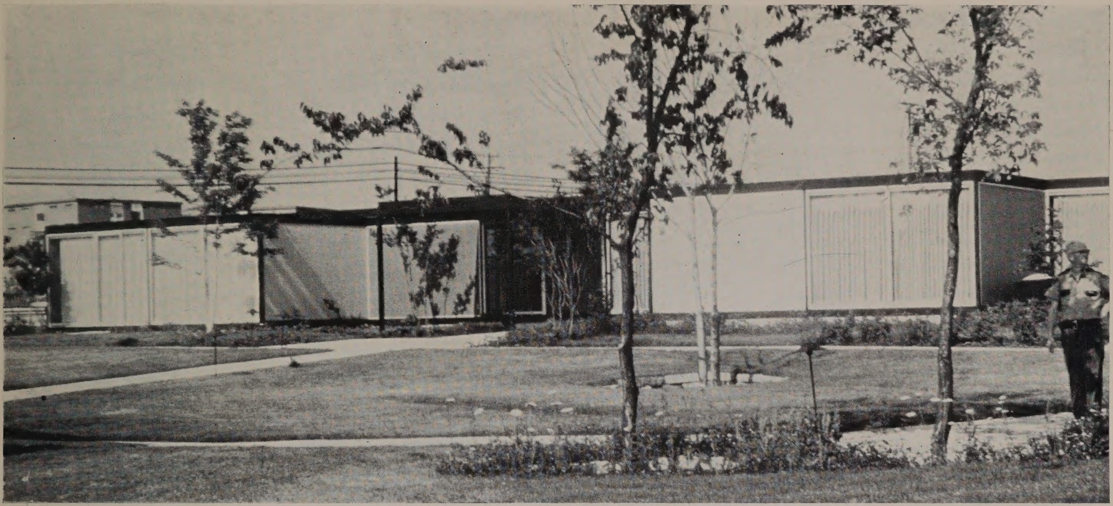
207. The rectangular steel tubes for the columns and beams are delivered in random lengths and the following operations are then carried out automatically: the tubes are fed on to a conveyor belt, cut to length, cleaned, and passed through a welding machine in which a selected combination of steel channel or angle connector sections is welded on. The components are then transferred to an overhead carrier system and passed through the stoving plant for painting and baking. In the production of wall panels, aluminium sheets of the correct size are fed into a revolving and continuously operating machine which applies adhesive to the inner surfaces, inserts steam probes, fills the panel with polystyrene beads, injects steam and allows curing time for the panels. The panels are then carried through a stoving plant which can apply 16 alternative colours. The roof and floor panel production lines are fed automatically from stacks of precut timbers and plywood sheets; the units are T-nailed and filled with foamed polystyrene. When visited, the factory had completed production trials and built a number of show houses, but had not yet gone into continuous production.

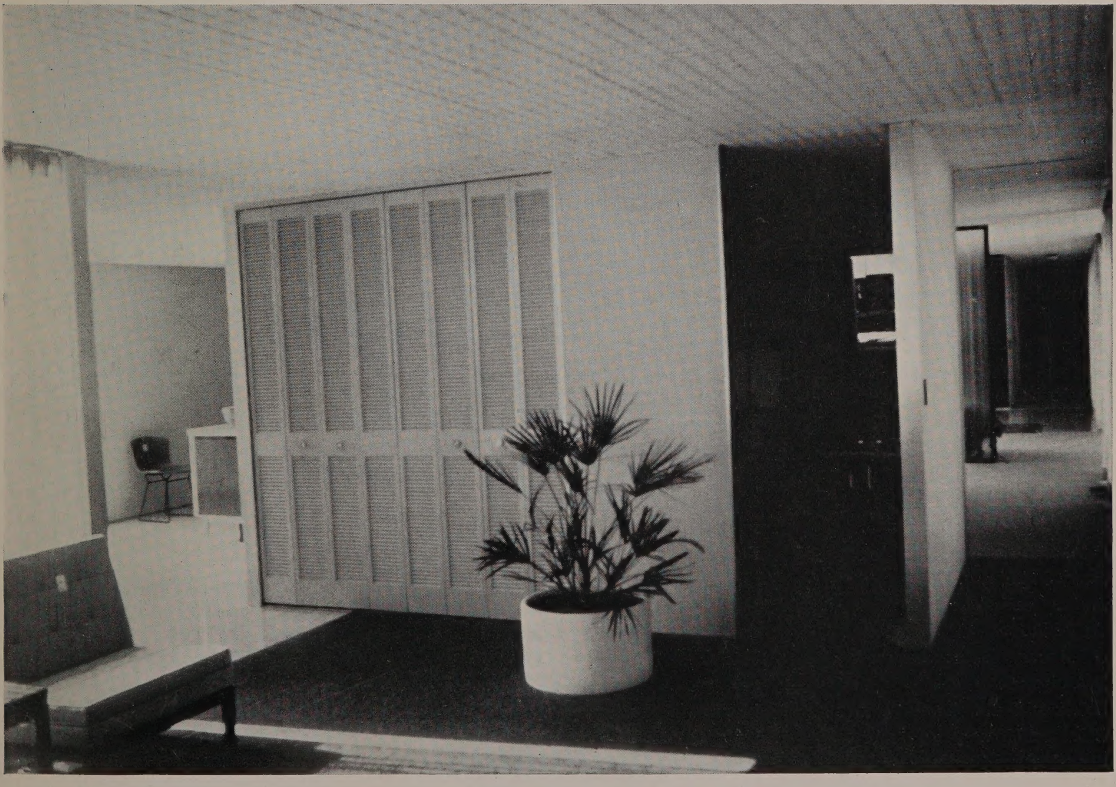
71 automated systems: external view

Manufacturer: Alside Homes Inc., Akron, Ohio.

72 automated systems: internal view

Manufacturer: Alside Homes Inc., Akron, Ohio.





Appendix 1

People and organisations visited

Acorn Structures Inc.	Concord, Mass.
Alside Homes Inc.	Akron, Ohio
American Plywood Association	Tacoma, Washington
Andrew Place and Company	South Bend, Ind.
Armco Steel Corporation	Middletown, Ohio
A.B.C. Package Co.	Healdsburg, Cal.
Dean Burnham Kelly	Cornell University
Prof. Glenn H. Beyer	Cornell University
Building Research Institute	Washington, D.C.
Continental Homes Inc.	Boones Mill, Va.
Deck Houses Inc.	Wayland, Mass.
Del E. Webb	Phoenix, Ariz.
Divco Wayne Corporation	Union City, Mich.
E. I. Du Pont and Co.	Wilmington, Del.
Farm Housing Administration	Washington, D.C.
Federal Housing Administration	Washington, D.C.
Fox and Jacobs	Dallas, Texas
Great Lakes Homes Inc.	Sheboygan Falls, Wis.
Holiday Homes	Fort Worth, Texas
Home Building Contractors Inc.	Sedelia, Missouri
Home Manufacturers Association	Washington, D.C.
Housing and Home Finance Agency	Washington, D.C.
R. J. Hunter Inc.	San Jose, Cal.
Kingsberry Homes Inc.	Chamblee, Ga.
Kit Construction Co.	Long Beach, Cal.
Knox Homes	Thompson, Ga.
Levitt and Sons Inc.	Levittown, N.J.
Maverick Homes	San Antonio, Texas
Mobile Homes Manufacturers Association	Chicago, Ill.
National Association of Home Builders	Washington, D.C.
National Bureau of Standards	Washington, D.C.
National Fiberglass Corporation	Fort Worth, Texas
National Homes	Lafayette, Ind.
National Lumber Manufacturers Association	Washington, D.C.
Robinson Newcomb, Esq.	Washington, D.C.
Northwest Homes Inc.	Chehalis, Washington
Pease Woodworking Co.	Hamilton, Ohio
Pauly and Company	Cincinnati, Ohio
Rohr Aircraft Corporation	Fullerton, Cal.
Sterling Custom Homes	Fond du Lac, Wis.
Harry Smith, Esq.	Chicago, Ill.
Trailer Coach Association	Los Angeles, Cal.
Techbuilt Inc.	Cambridge, Mass.
U.S. Forest Research Laboratory	Madison, Wis.
U.S. Gypsum	Chicago, Ill.
U.S. Steel Research Laboratories	Monroeville, Pa.
U.S. Steel Homes	New Albany, Ohio
Weyerhaeuser Company	Tacoma, Washington

Appendix 2

Books

The Evolving House	A. F. Bemis	1933
Prefabrication of Houses	Burnham Kelly	1951
Housebuilding in Transition	S. J. Maisel	1953
Housing: A Factual Analysis	Glenn H. Beyer	1958
Design and the Production of Houses	Burnham Kelly and Associates	1959
Housing, People and Cities	Meyerson, Terrett and Wheaton	1962

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FOR THE PROMOTION

OF HEALTH

Founded 1876

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—January, 1965

Printed and published by
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S.O. Code No. 75-149